IMAT Webinar

19th of May 2022

The Research Council of Norway

masterly
a Kongsberg Wilhelmsen joint venture

KONGSBERG

SINTEF

NTNU

Reference Group

KYSTVERKET

Sjøfartsdirektoratet
Norwegian Maritime Authority

Trondheim Havn

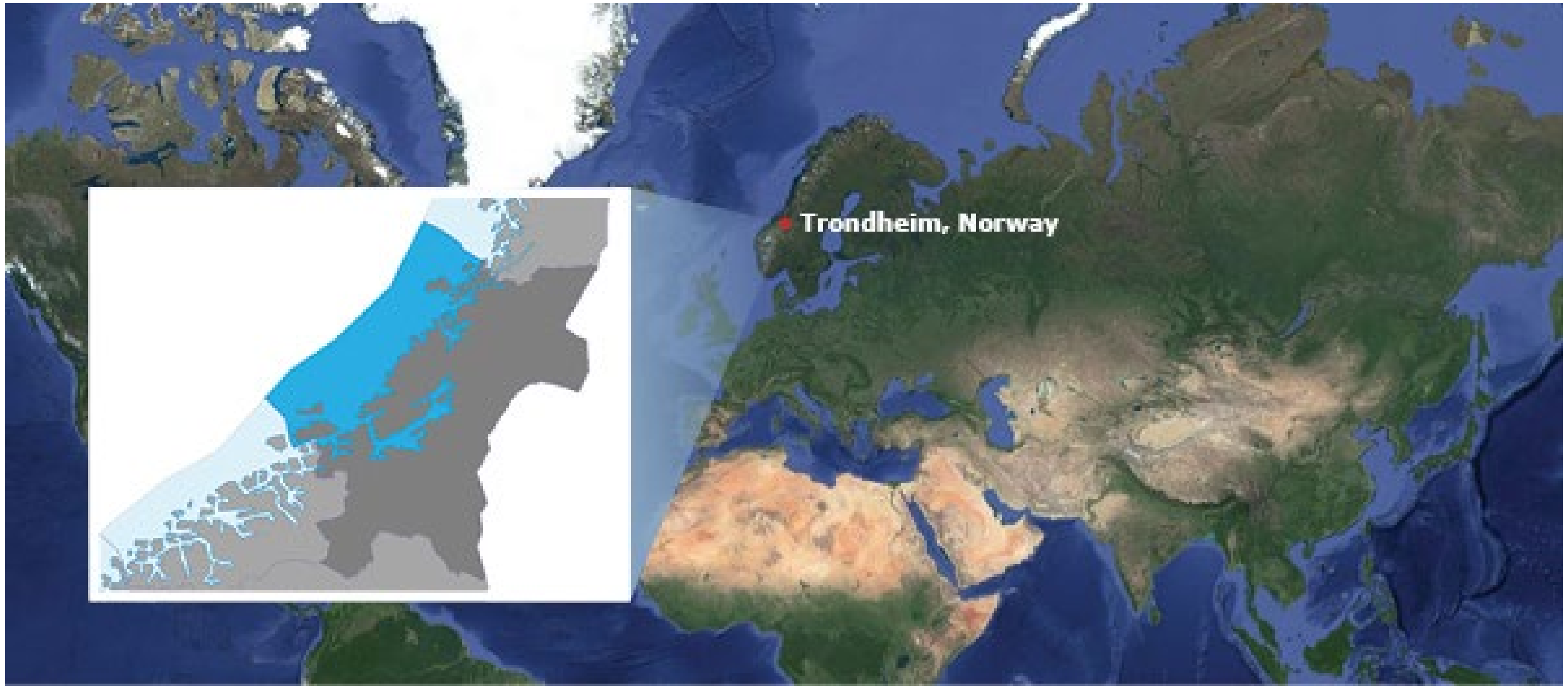
Agenda

- Trondheimsfjorden Test Area for Autonomous Ships
- The IMAT project
- Demonstration
- Possibilities

Integrated Maritime Autonomous Transport Systems

Trondheimsfjorden Test Area for Autonomous Ships

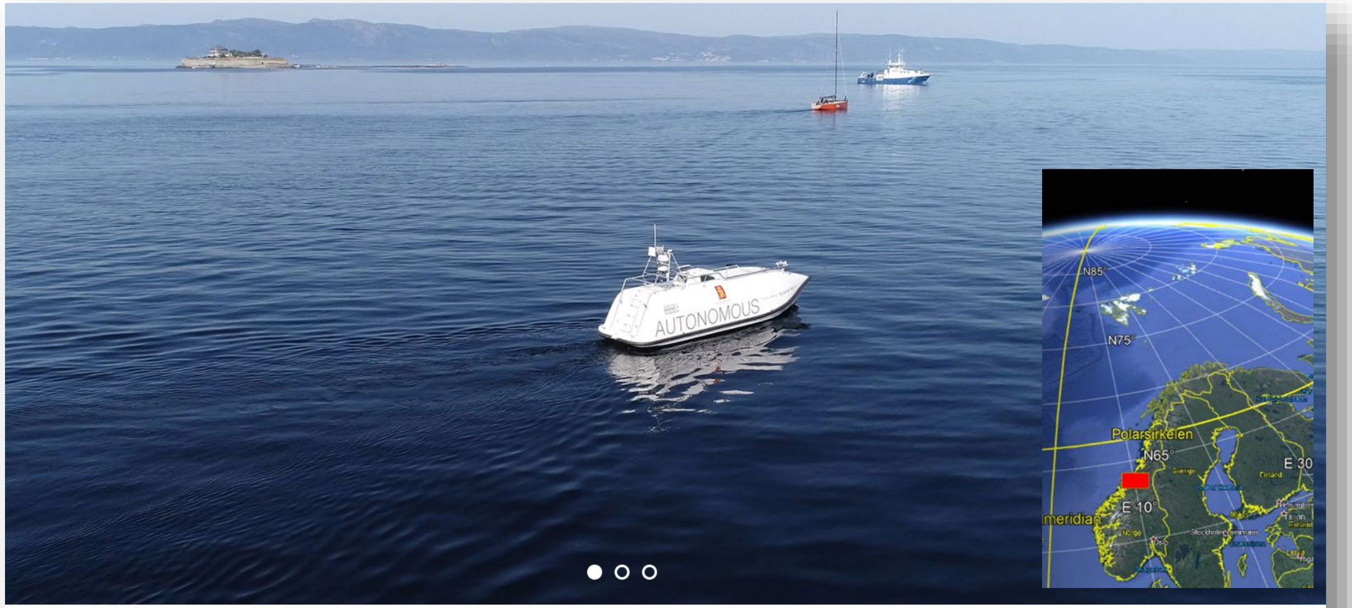
"Leading the transformation of shipping"



KONGSBERG NTNU MARITIME ROBOTICS Trondheim Havn KYSTVERKET NORWEGIAN COASTAL ADMINISTRATION Sjøfartsdirektoratet Norwegian Maritime Authority OCEAN AUTONOMY CLUSTER DNV·GL SINTEF

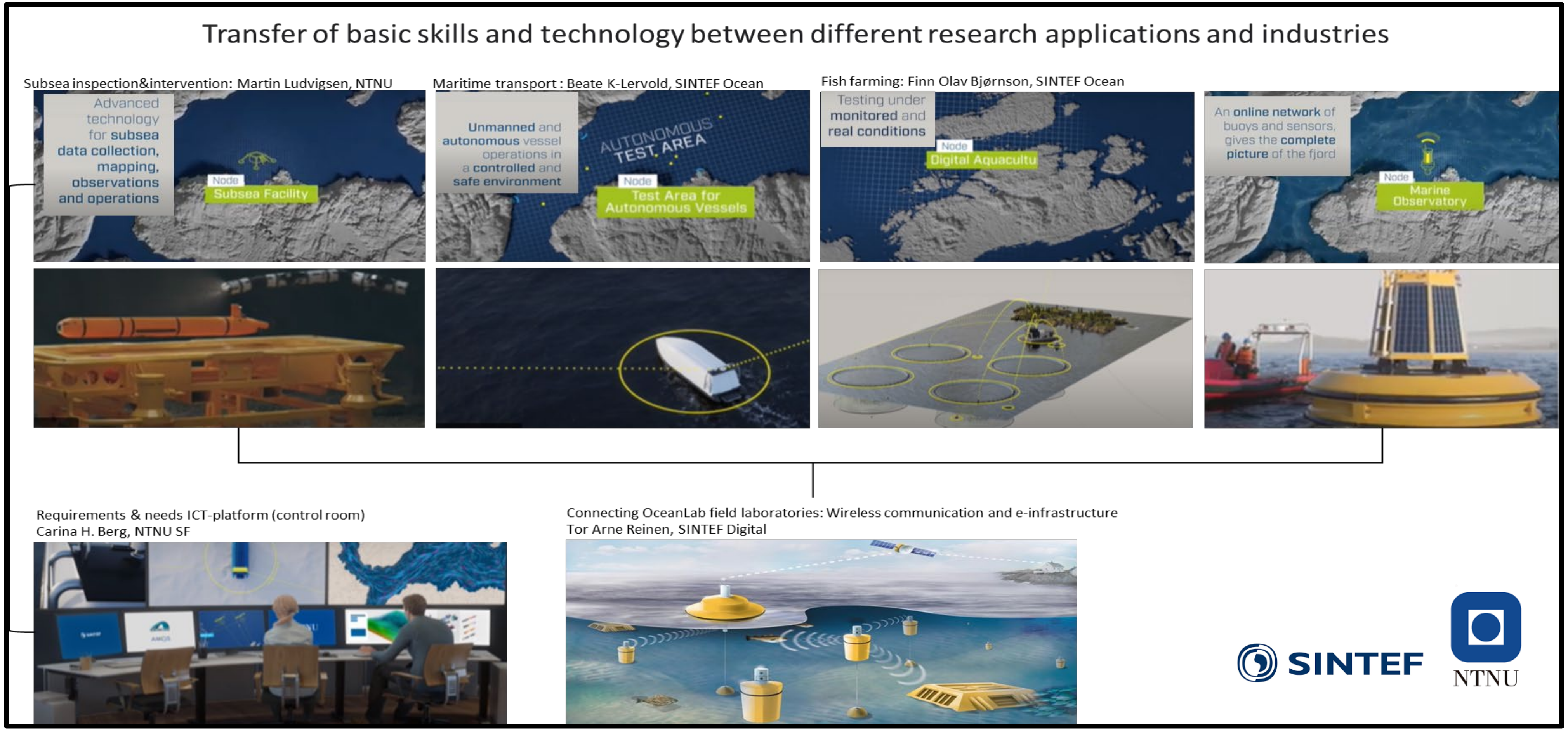
Trondheimsfjorden Test Area for Autonomous Ship

1. Founded in 2016
2. Foster knowledge building
3. Stimulate technology development
4. Drive innovation
5. Develop rules and regulations
6. Test and verify concepts and solutions
7. Collaboration with other test sites and initiatives
   - SAMS, OAC, Storfjorden, INAS, NFAS, …
   - ESA, EU and the Research Council of Norway
   - Between projects, academia, government, researchers and industry



Trondheimsfjorden: World's first test site for autonomous ships

Trondheimsfjorden Test Area for Autonomous Ship – a "sandbox" for autonomous ships



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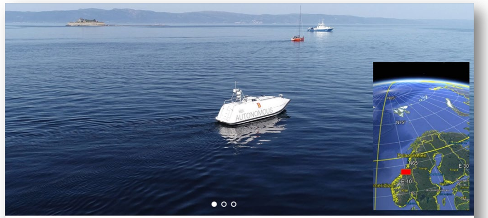


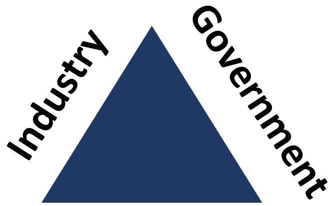
Trondheimsfjorden: World's first test site for autonomous ships

Trondheimsfjorden Test Area for Autonomous Ship – a "sandbox" for autonomous ships

imat
Integrated Maritime
Autonomous Transport Systems

Users of the fjord:

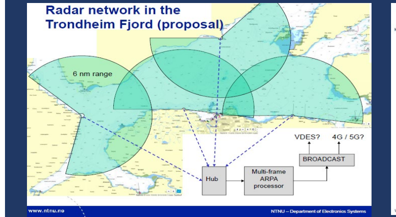
- Government
- Academia
- Research
- Industry
- Service providers
- Infrastructure owners
- Maritime community
- ESA, EU, Innovation Norway, Norwegian Research Council, etc

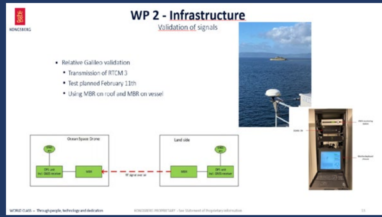


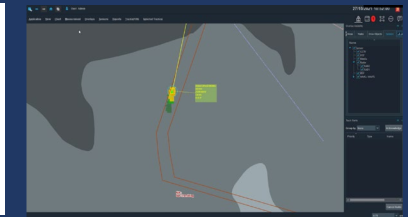
Research and academia

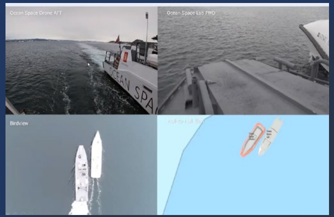
Logistic opportunities

Communication and navigation opportunities

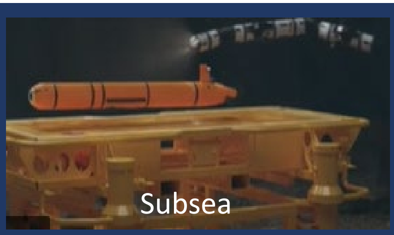


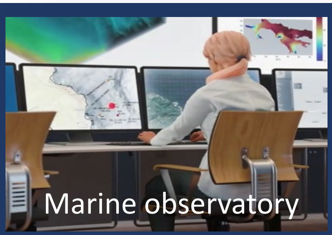






Operational opportunities





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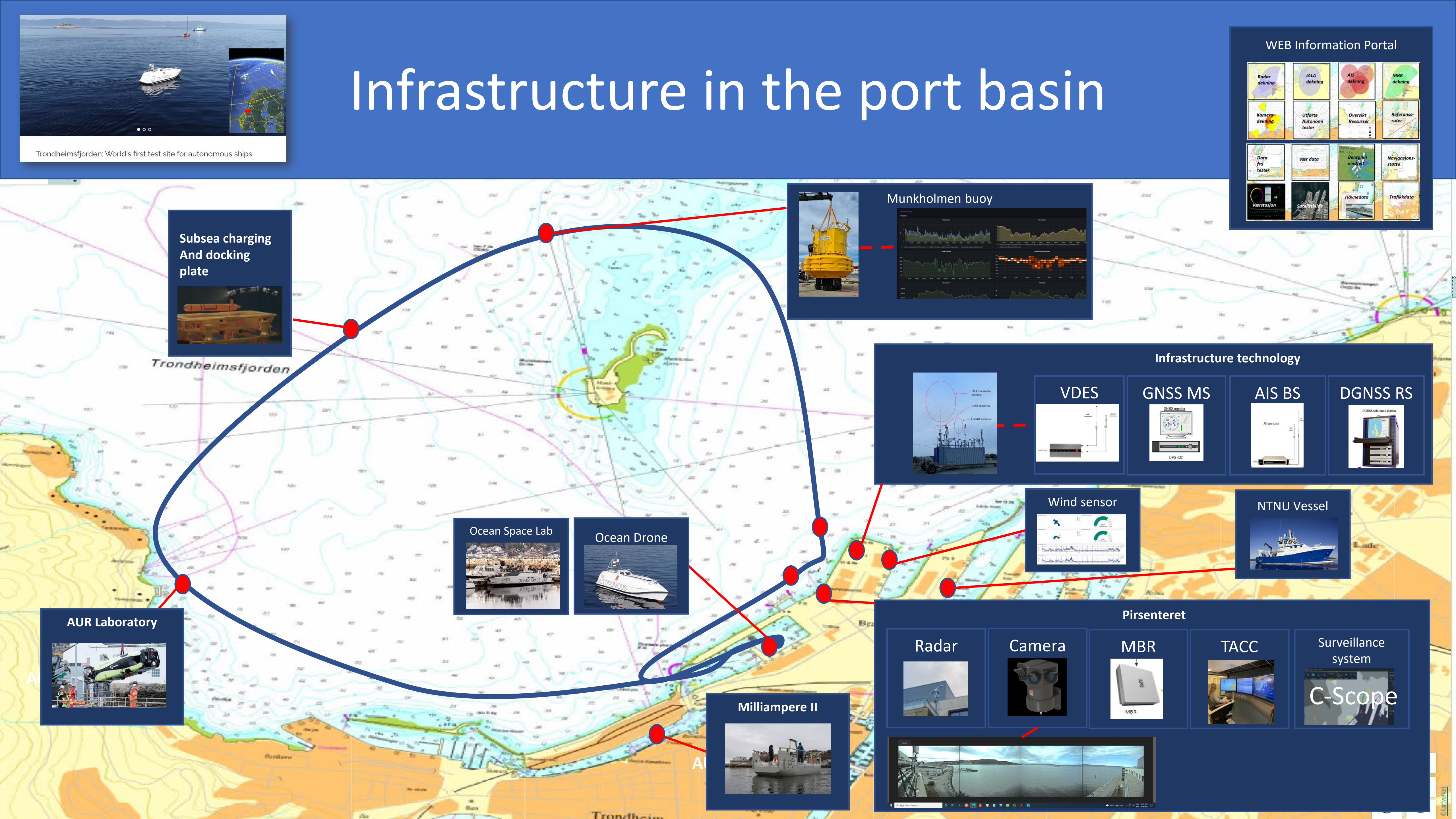

Infrastructure in the port basin
Trondheimsfjorden: World's first test site for autonomous ships
WEB Information Portal
Radar dekning
IALA dekning
AIS dekning
MBR dekning
Kamera dekning
Utførte Autonomi tester
Oversikt Ressurser
Referanse-ruter
Data fra tester
Vær data
Beregnin vindfelt
Navigasjons-støtte
Værstasjon
Satellittbilde
Havnedata
Trafikkdata
Munkholmen buoy
Subsea charging
And docking
plate
Trondheimsfjorden
Infrastructure technology
VDES
GNSS MS
AIS BS
DGNSS RS
Wind sensor
NTNU Vessel
Ocean Space Lab
Ocean Drone
AUR Laboratory
Pirsenteret
Radar
Camera
MBR
TACC
Surveillance system
C-Scope
Milliampere II

The IMAT Project

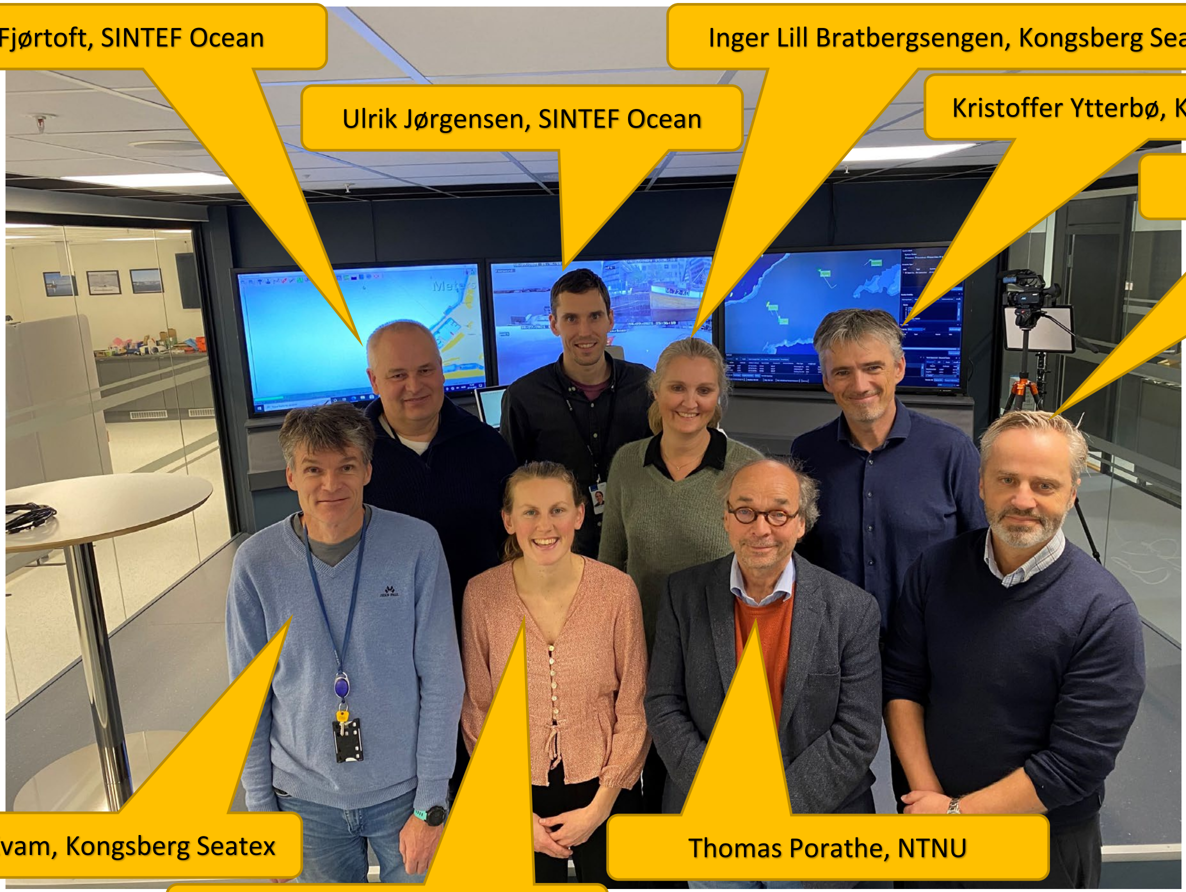
- Integrated Maritime Autonomous Transport Systems

To specify, adapt and develop technology to support maritime autonomous transport systems by focusing on:

- **Sensor- and communication infrastructure**
- **Data Centre/information centre**
- **Land-based operation centre (TACC/ROC/SCC)**
- **Traffic**

Integrated Maritime Autonomous Transport Systems

The IMAT Project Team



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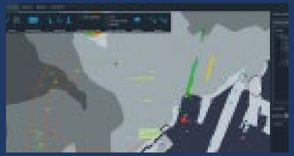
The IMAT project scope

The IMAT project has developed and tested land-based sensors, communication systems and control systems which have been used as a support to the navigation and operation of autonomous vessels. The technological infrastructure is able to provide the transportation systems with increased sensor redundancy and will be an integrated part of the shorebased control centres, which shall ensure safe and efficient operations. A reliable infrastructure is crucial for a safe implementation of maritime autonomous transport systems. The main objective of the IMAT project is to define, develop, adapt and test the land-based sensor infrastructure.

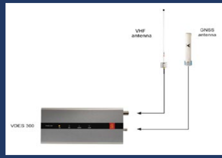
Information portal

ROC

Surveillance system



VDES



Camera

Infrastructure

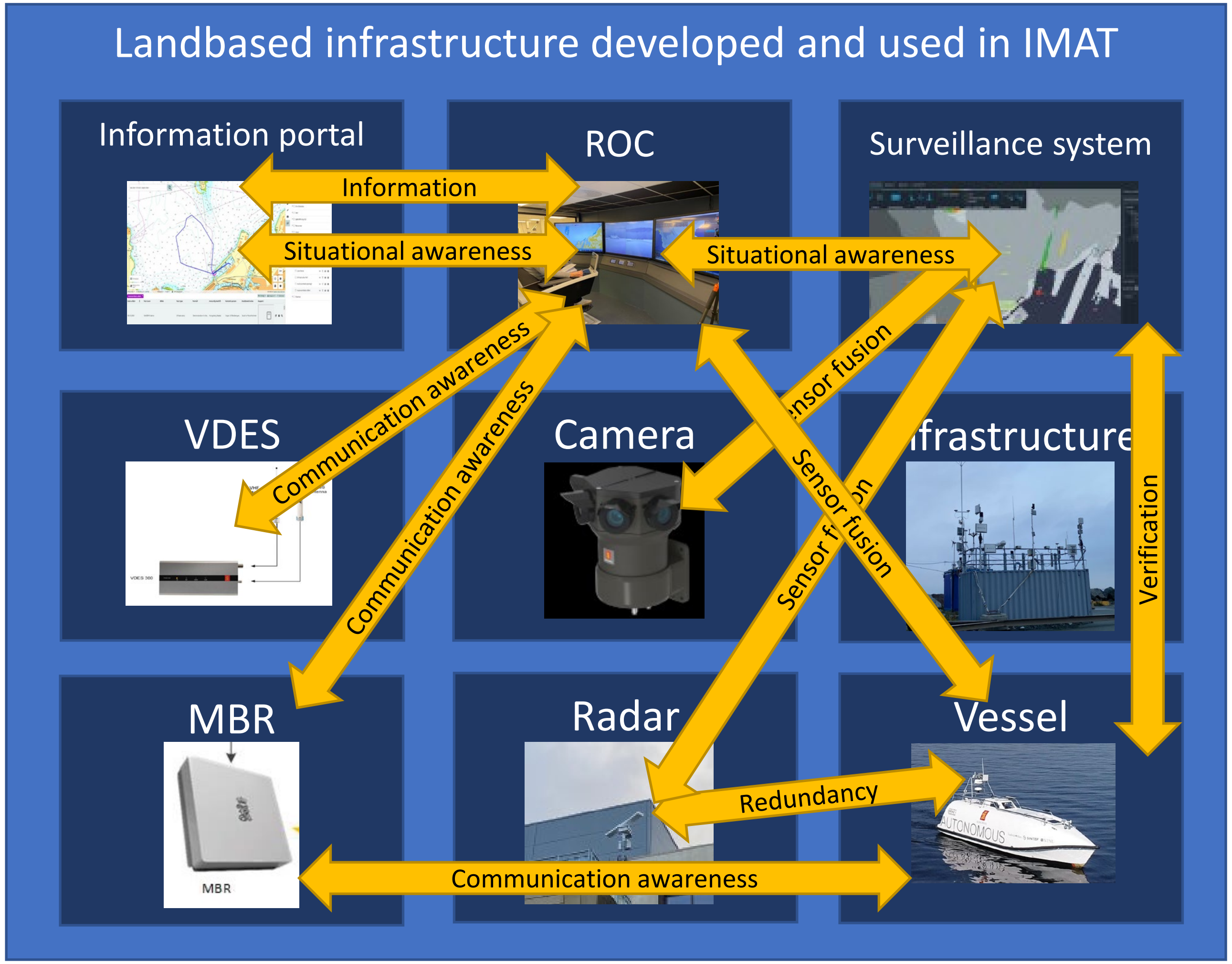
MBR

Radar

Vessel

The IMAT project scope

Integrated Maritime
Autonomous Transport Systems



Why?

- ***Sensor redundancy***
- ***Sensor fusion***
- ***Situational awareness***
- ***Verification of technology***
- ***Communication awareness***
- ***Demonstration of usability***

Project Structure

imat

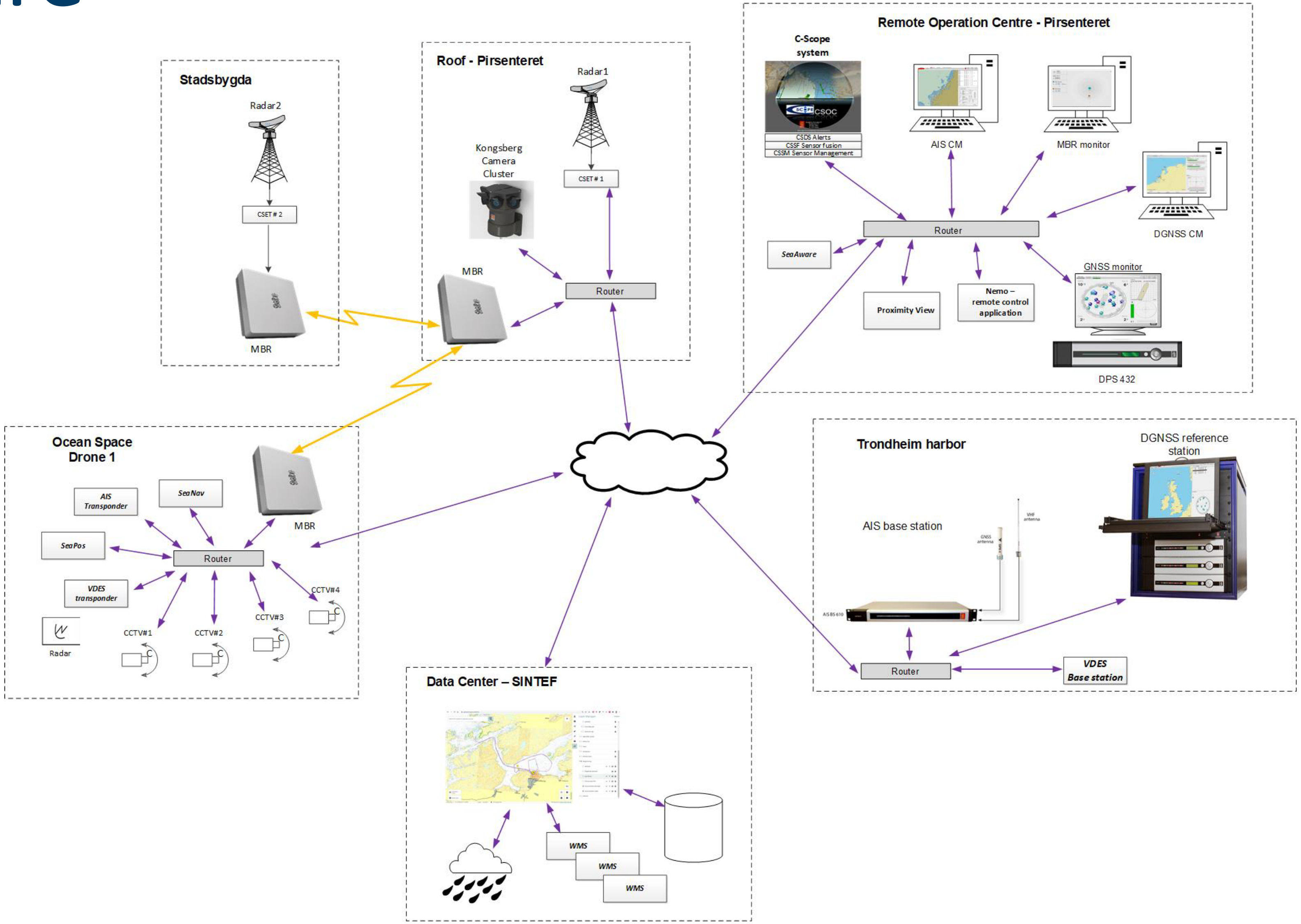
Integrated Maritime
Autonomous Transport Systems

H1 - Infrastructure

- Descriptive study of possible sensors and communication systems used for land-based infrastructure
- Looked into performance parameters and requirements for sensors and communication systems
- Discussed what types of land-based infrastructure could assist in bringing awareness to the decision-making used to control and support a MASS operation
- Establish infrastructure in the test area

H1 - Infrastructure

- Established infrastructure in the area including navigation and communication equipment
- Established a remote operation centre
- Connected all parts in one network including vessels



Integrated Maritime
Autonomous Transport Systems

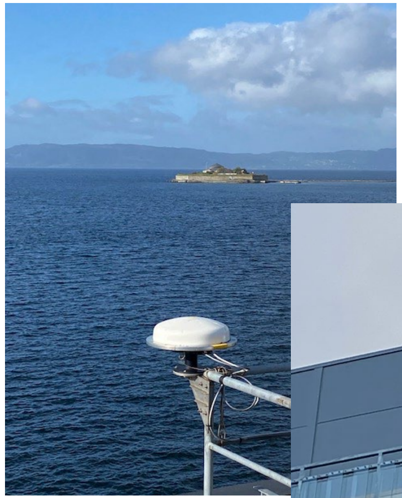
H1 - Infrastructure

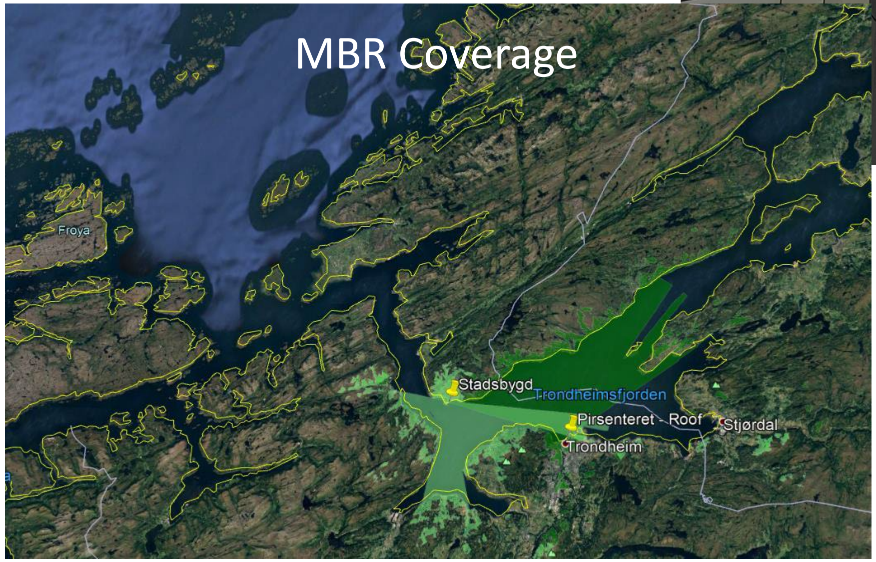
A broadband communication network has been established

- Installed one **Maritime broadband radio** (MBR) on the roof of Pirsenteret
- One **MBR** unit installed on the wall at Stadsbygda, across the fjord from Pirsenteret
- Mobile **MBR** units on the vessels Ocean Space Lab and Ocean Space Drone 1

Two radars have been established in the area

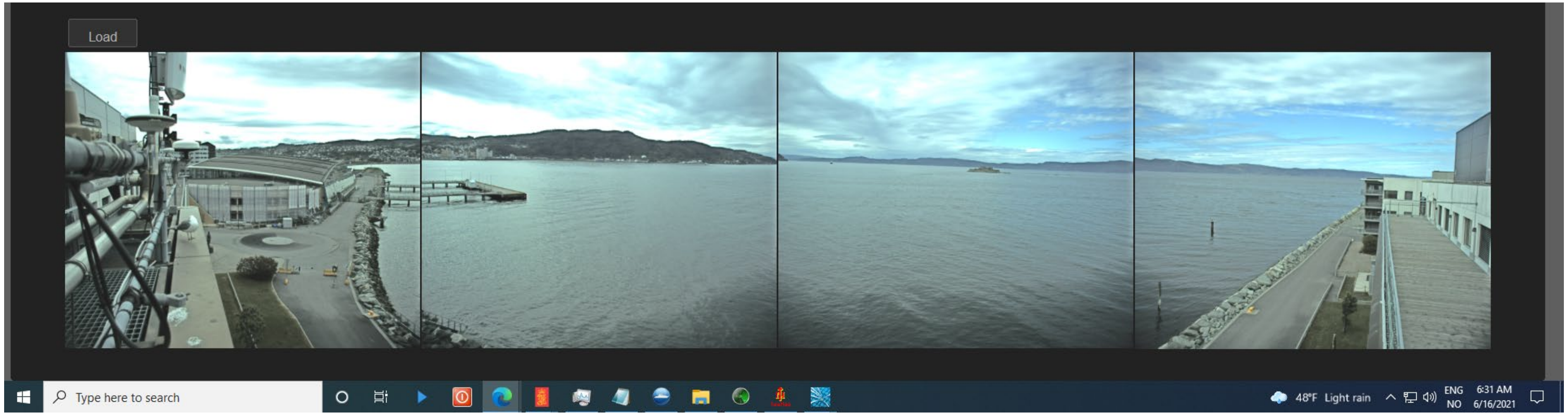
- One **radar** is installed on the roof of Pirsenteret
- One **radar** is installed in Stadsbygda, across the fjord from Pirsenteret
- Data from the radar at Stadsbygda is transmitted to the control centre in Pirsenteret via MBR.





H1 - Infrastructure

- A **Kongsberg Camera Cluster (KCC)** is installed on Pirsenteret together with **SeaAware** and **ProximityView**. Improves the situational awareness enabled by artificial intelligence and machine learning techniques in combination with traditional sensor fusion.
- An **AIS base station** and a **VDES base station** is established in Trondheim harbor



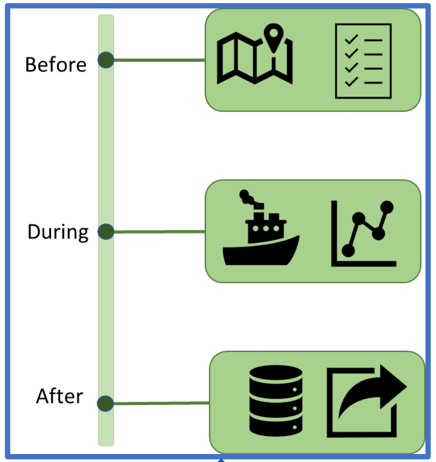
H1 - Infrastructure

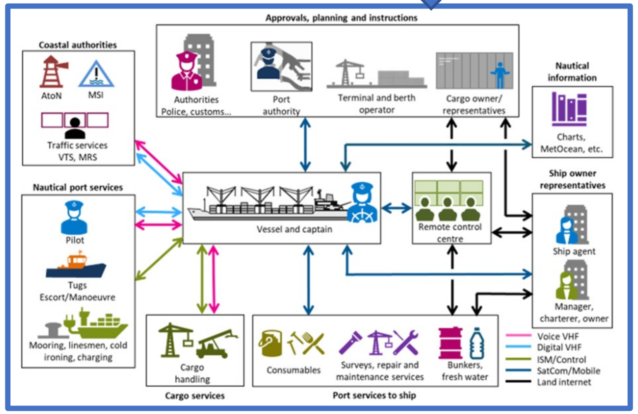
A Remote Operation Center has been established

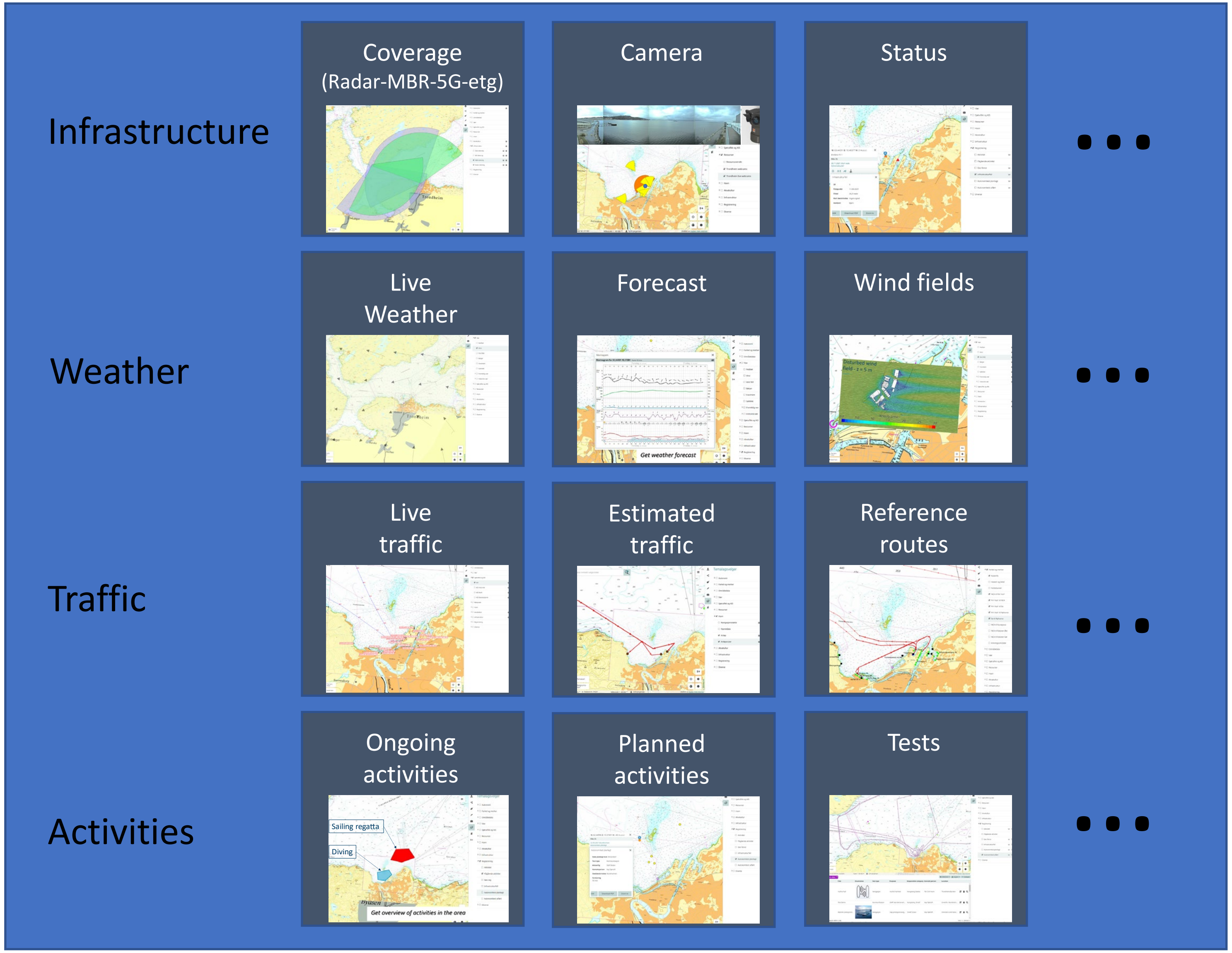
- Operates as **a monitoring and control center** for the established infrastructure
    - Radars
    - AIS and VDES base station
    - MBR network
    - Camera Cluster
    - C-Scope
    - Data Centre
- Possible to configure and monitor the installed equipment
- Communicates with installed equipment and the KSX vessels via Ethernet/4G and MBR

H2 - Information

Integrated Maritime Autonomous Transport Systems



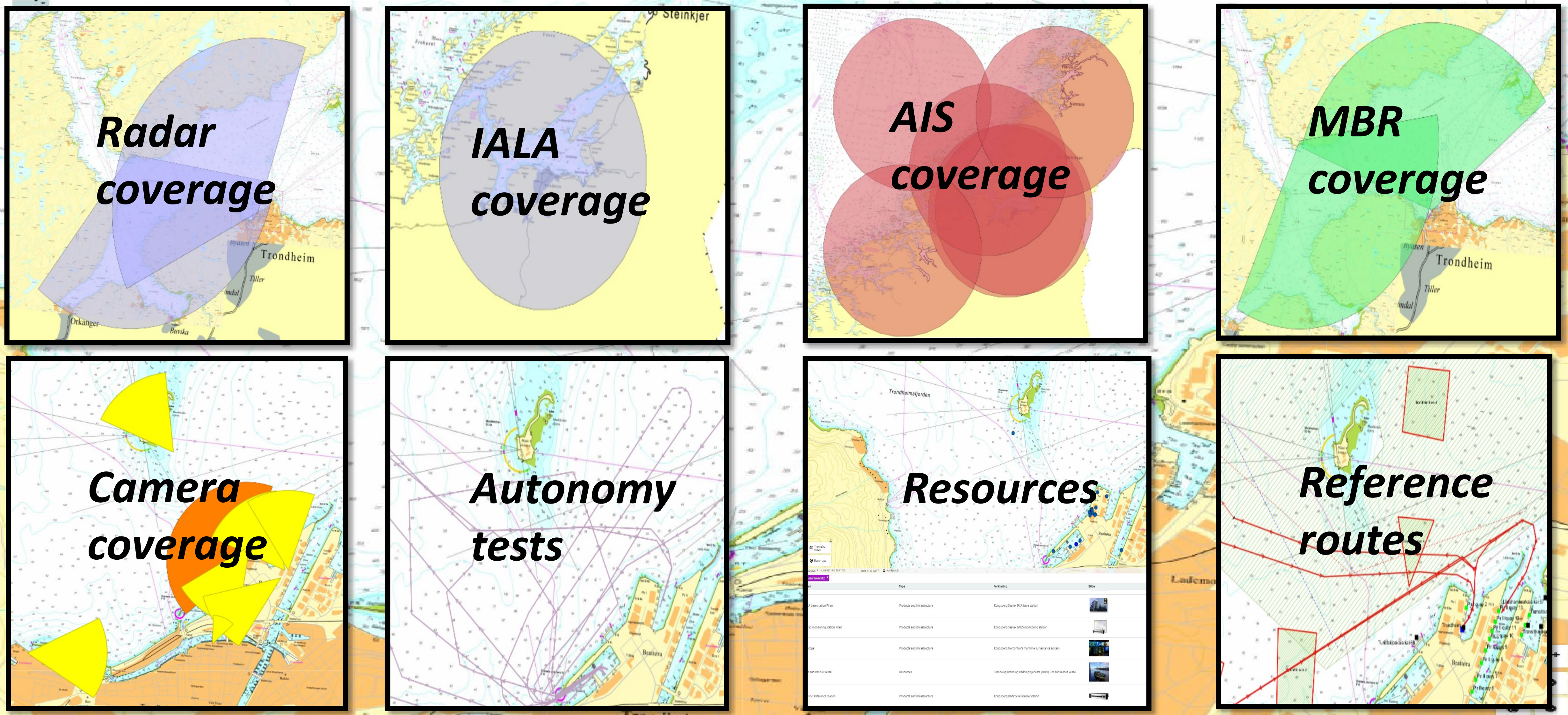




Support from: Meteorologisk institutt, KYSTVERKET, asplan viak

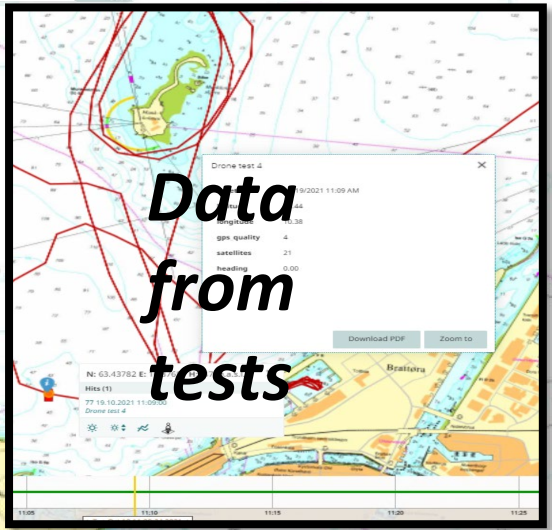
H2 - Information portal

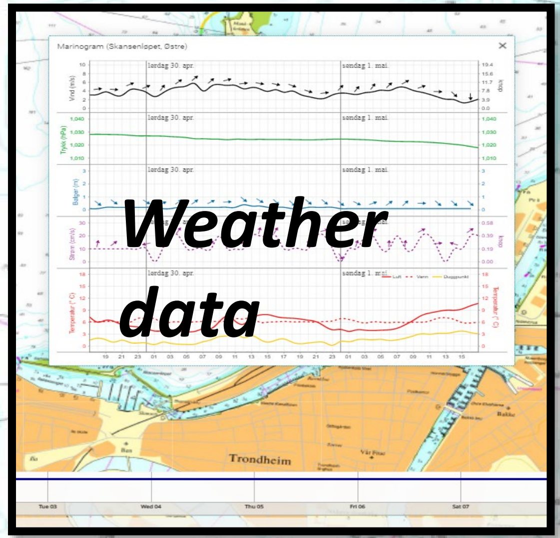
Support from:

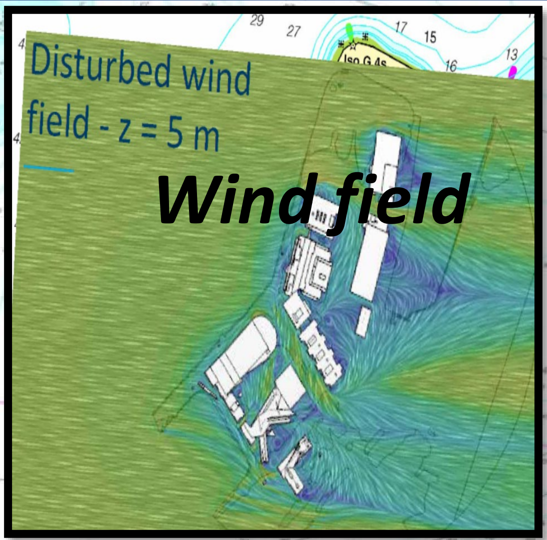


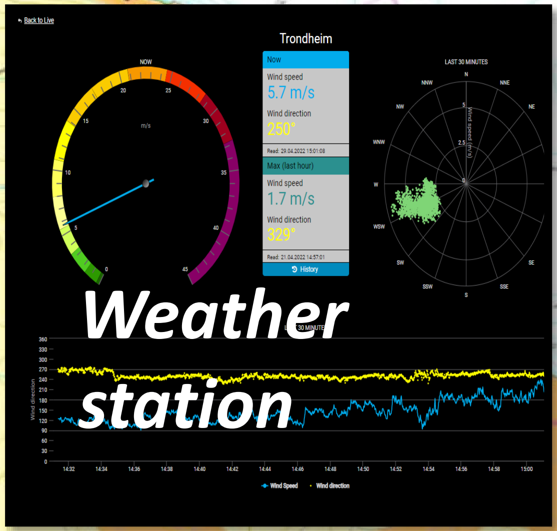
H2 - Information portal

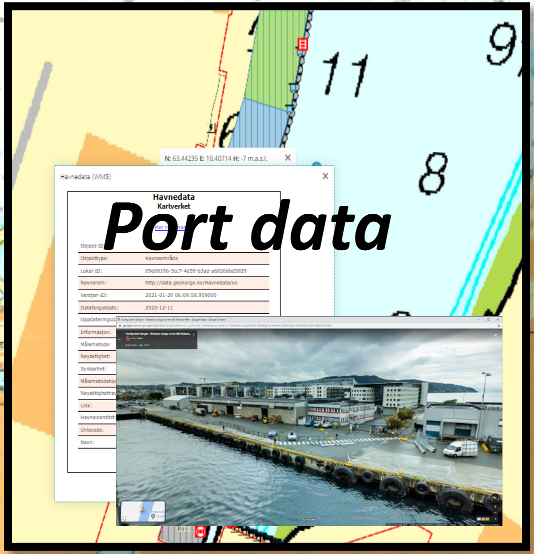
Support from:
Meteorologisk institutt
KYSTVERKET
asplan viak

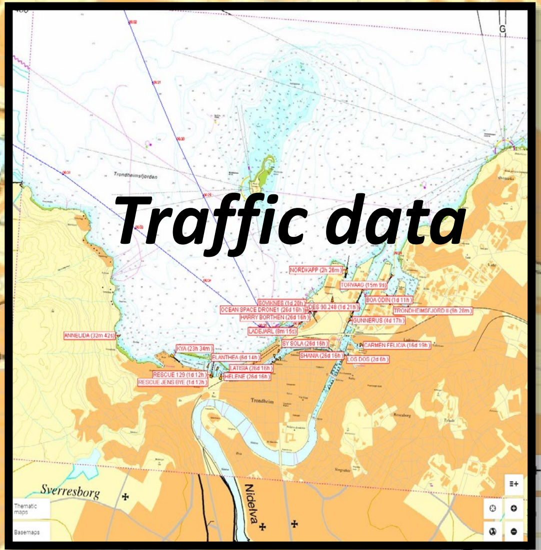








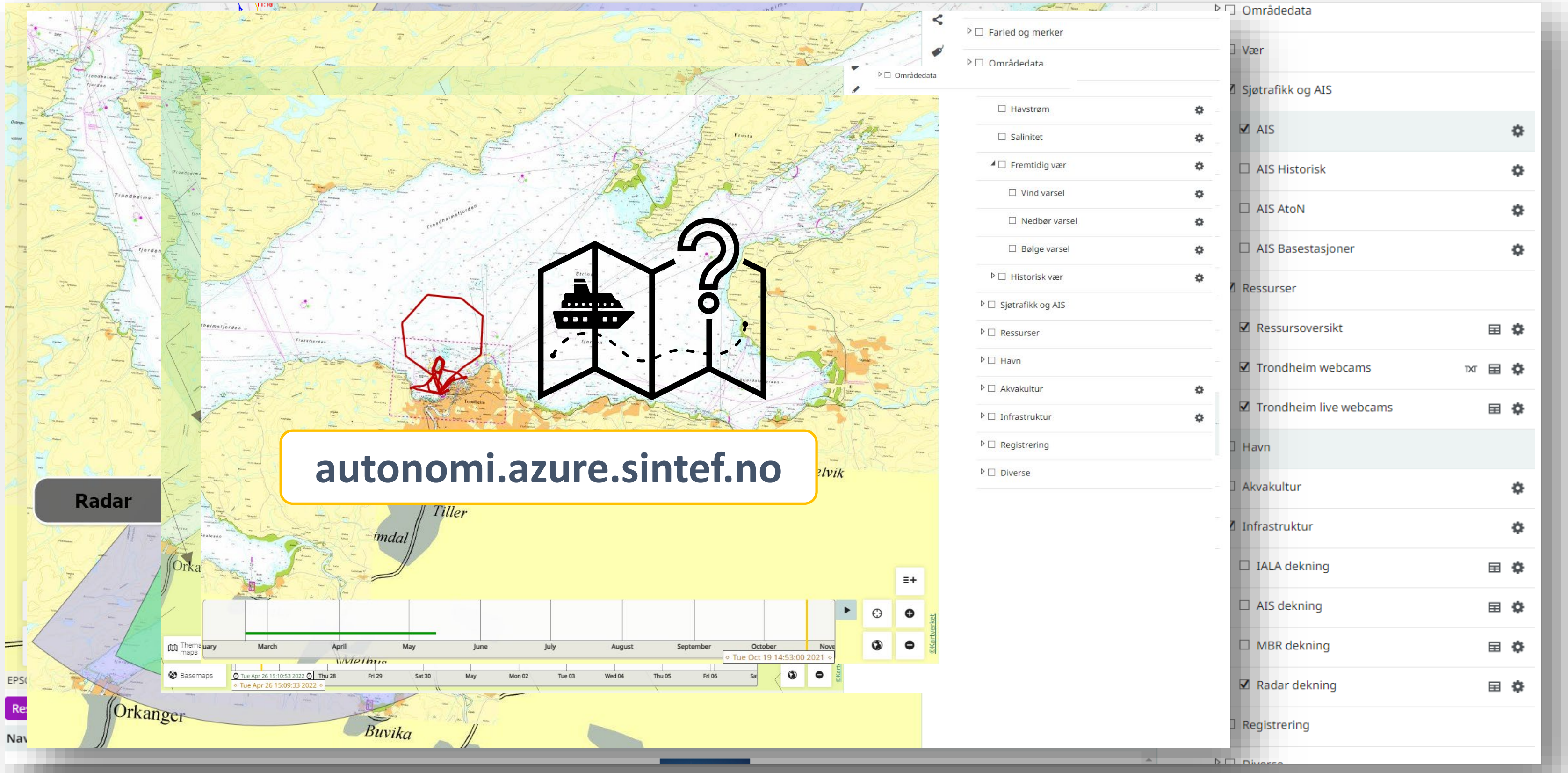




Integrated Maritime
Autonomous Transport Systems

H2 - Information

- Installed software
  - Adaptive
  - MS Azure VM
  - MS Azure Database
- Integrate with available information services
  - Met.no (meteorological data)
  - Kystdatahuset (traffic data)
  - Kystverket
- Identify required functionalities
  - User login/data restriction
  - Import/export functionalities
  - Resister and share tests



H3 - Remote Control Centres

Levels of autonomy


Remote operation centre

Illustrasjon: Naval Dynamics

7. Full autonomy

6. Limited autonomy - no crew on board, vessel monitored and can be controlled from control room (ROC)

5. Partly unmanned - crew on board who are called by ROC when needed

4. Remote operation - crew on board but vessel controlled from control room (ROC)

3. Remote monitoring - crew on board but the systems are monitored from control rooms (ROC)

2. Crew on board but automation has control

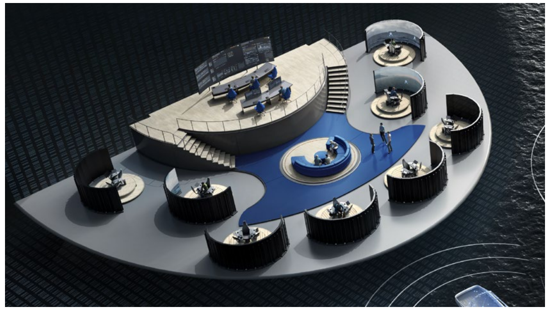
1. Crew has direct control

ROC involvement (levels 3–6)

Human involvement (levels 1–6)

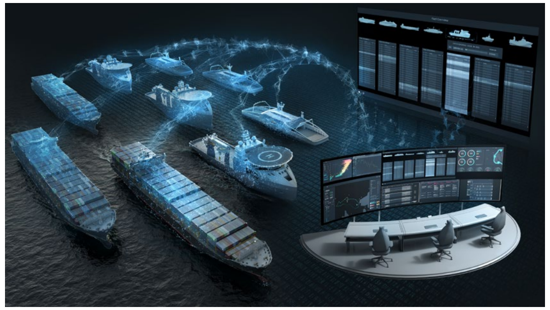
Building blocks for Remote and Autonomous Operations

Integrated Maritime Autonomous Transport Systems



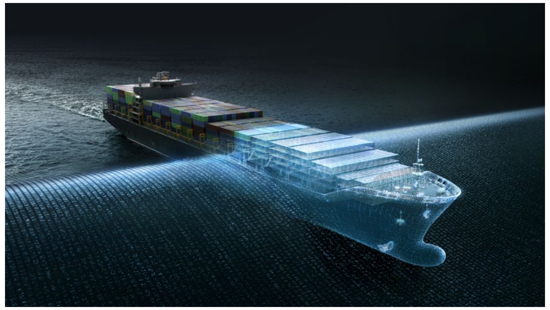
REMOTE OPERATIONS CENTRE

Enabling remote operations of vessels and other floating assets in a safe, efficient and secure manner.



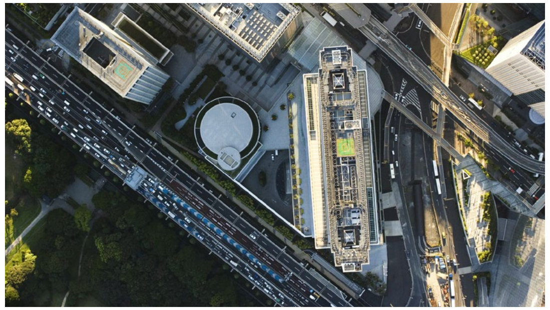
CONNECTIVITY SYSTEM

Enabling secure and safe connection between the ROC and fleet of vessels.



VESSEL SYSTEMS

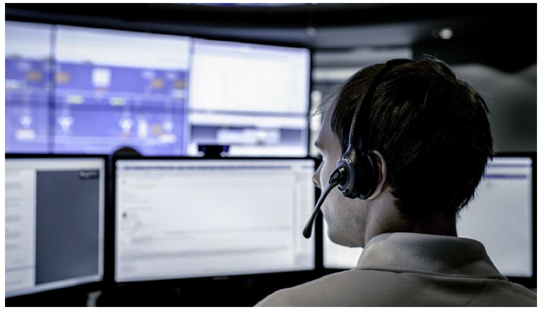
Enabling remote & autonomous operations with key digital orchestrators and existing products.

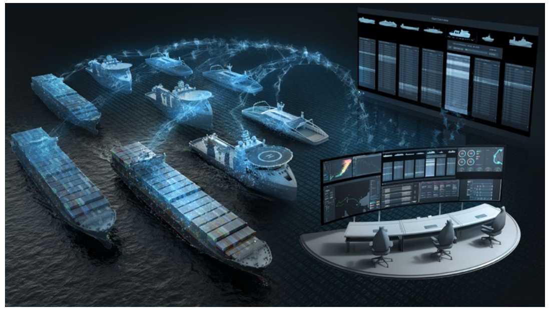


VESSEL OPERATOR

Providing required infrastructure and procedures for remote & autonomous operations.

Categories of operations





REMOTE SUPPORT

Empowering the onboard crew by **remote monitoring** and **support** in an expert in the loop setting.

REMOTE CONTROL

Enabling manned/unmanned vessel operations from a remote location with **direct control** capability.

Alleviate the workload of the onboard crew by providing **assisted control** capability.

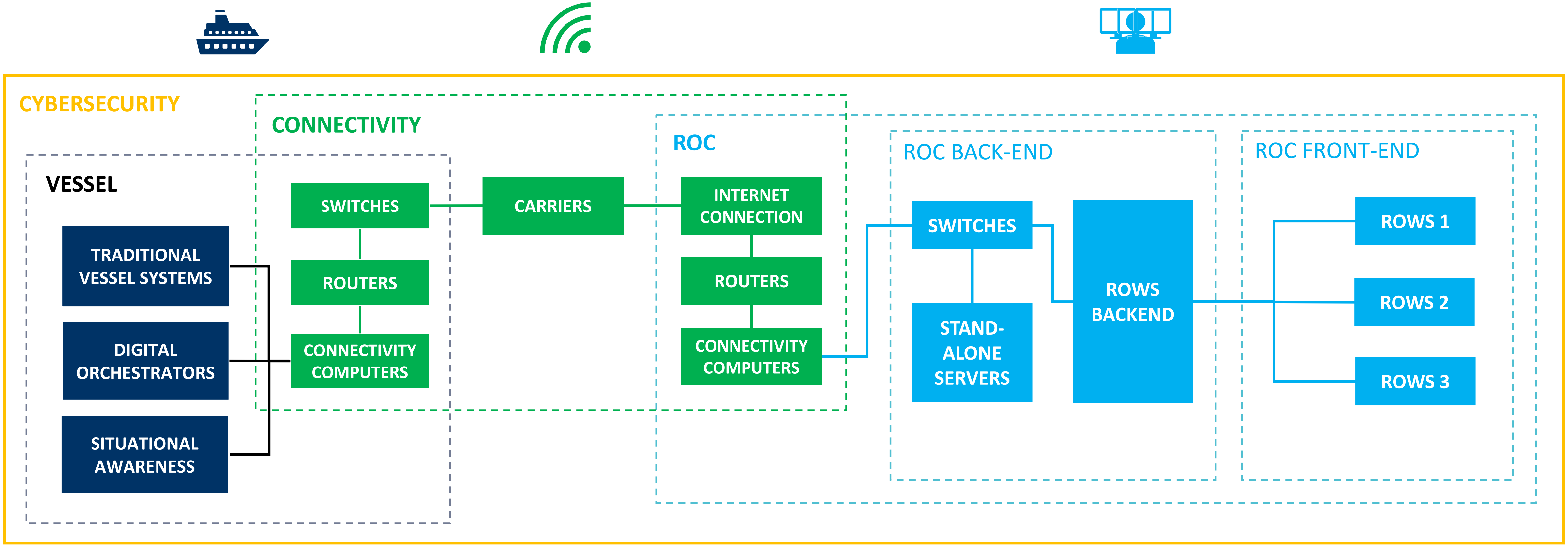
AUTONOMOUS

Autonomous vessel operations with **monitoring, supervision** and **intervention** capability from a remote location.

FLEET

Large scale fleet operations solution including **mission management, planning, scheduling, resource management** supplementary to other categories of operations.

Topology


CYBERSECURITY
CONNECTIVITY
VESSEL
TRADITIONAL VESSEL SYSTEMS
DIGITAL ORCHESTRATORS
SITUATIONAL AWARENESS
SWITCHES
ROUTERS
CONNECTIVITY COMPUTERS
CARRIERS
ROC
INTERNET CONNECTION
ROUTERS
CONNECTIVITY COMPUTERS
ROC BACK-END
SWITCHES
STAND-ALONE SERVERS
ROWS BACKEND
ROC FRONT-END
ROWS 1
ROWS 2
ROWS 3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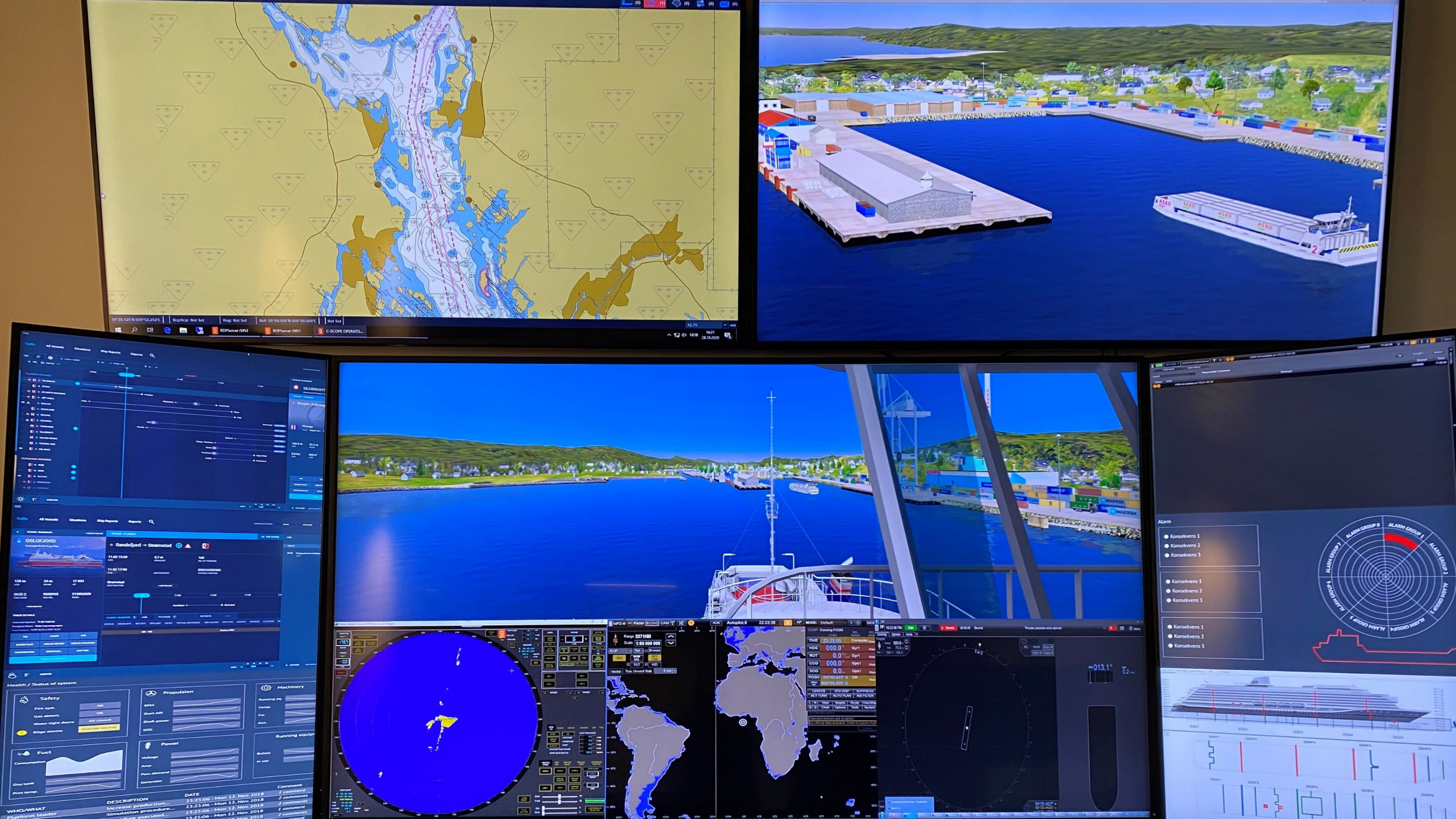
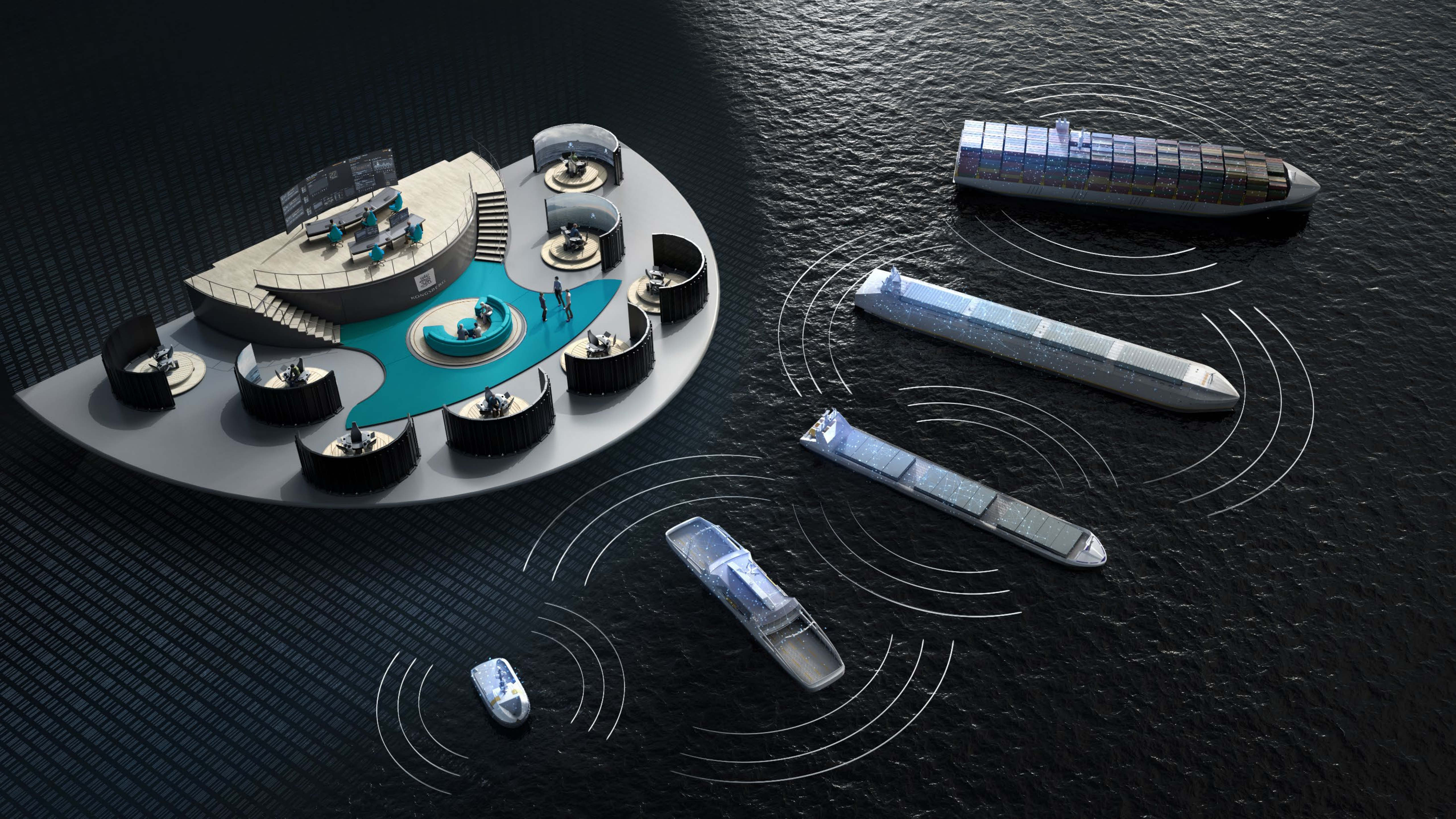


Alarm
Konsekvens 1
Konsekvens 2
Konsekvens 3
Konsekvens 1
Konsekvens 2
Konsekvens 3
Konsekvens 1
Konsekvens 2
Konsekvens 3
OSLOFJORD
Sandefjord → Strømstad
Health / Status of system
Safety
Propulsion
Machinery
Fuel
Power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Massterly's ROC in Horten is co-located with ASKO Maritime

Integrated Maritime Autonomous Transport Systems

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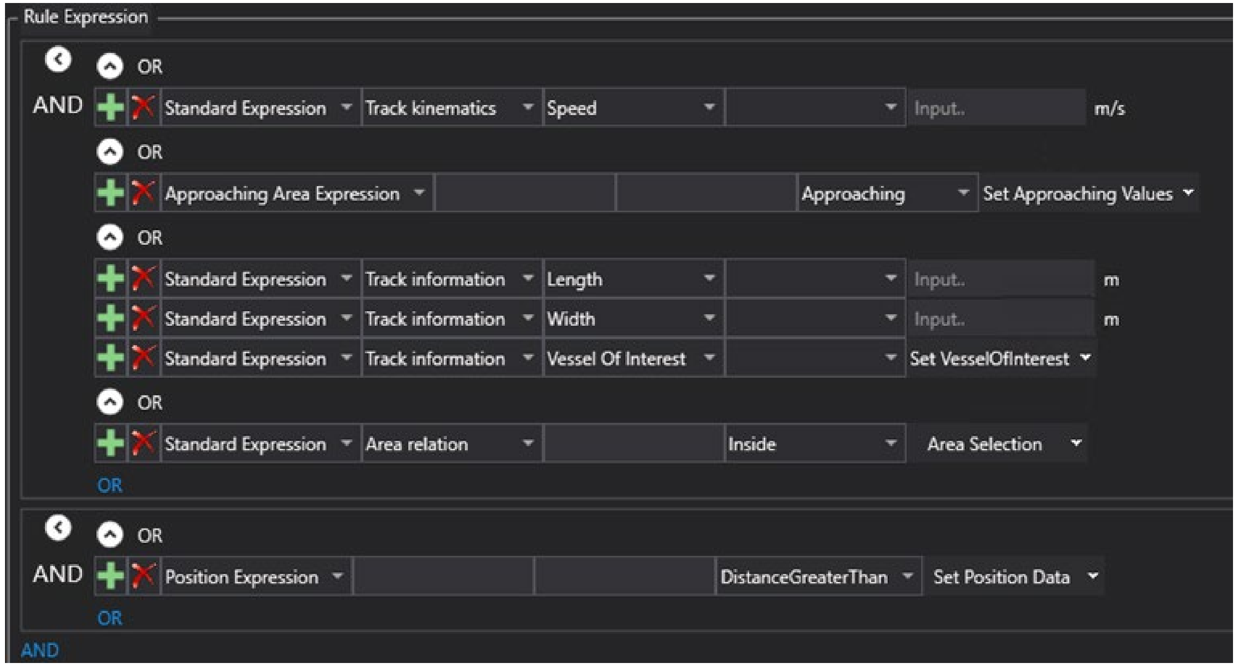
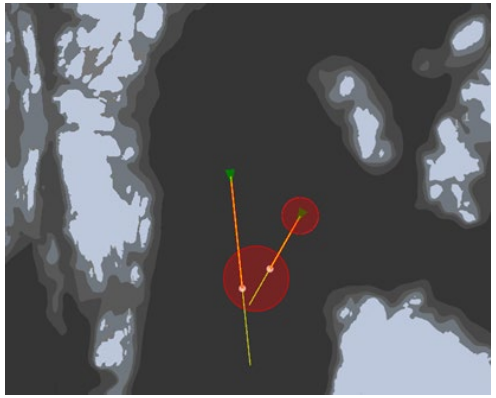
H4 - Traffic

- Identify stakeholders and regulations in the test area
- Map available sensors that will improve the situational awareness in a Remote Operating Center for autonomous operations
- Investigate how ship-shore communication can enhance the decision support tools in a ROC
- Establish scenarios to demonstrate how land based Maritime Domain Awareness systems and sensors from Kongsberg are used to improve situational awareness and decision support tools for operators in a Remote Operation Center for autonomous ships
- Adapt and install C-Scope in the ROC.
- Shared situational awareness with authorities and other stakeholders

H4 – Traffic / Infrastructure

- **C-Scope real time traffic image compilation**
- **C-Scope Sensor fusion - ship and shore sensors**
- **C-Scope Decision support:**
  - Collision Avoidance
  - Early warning
  - Abnormal behavior detection
  - Congestion avoidance
  - Right on time arrival
  - Route management and optimization
  - Route exchange functionality
  - Rules and regulations
  - Prediction (Traffic management)
- **C-Scope Sensor Management - ship and shore:**
  - Radar, AIS, Cameras, Ship sensors - SeaAware (KCC), Met/Hyd





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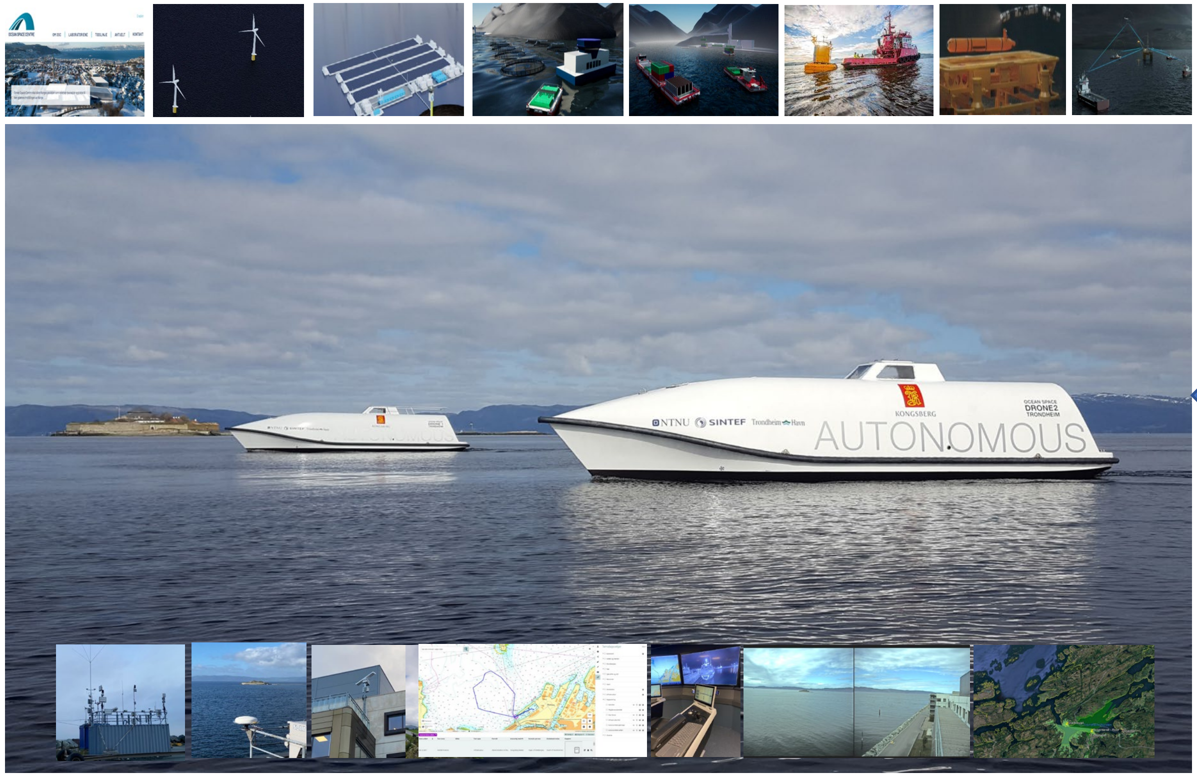
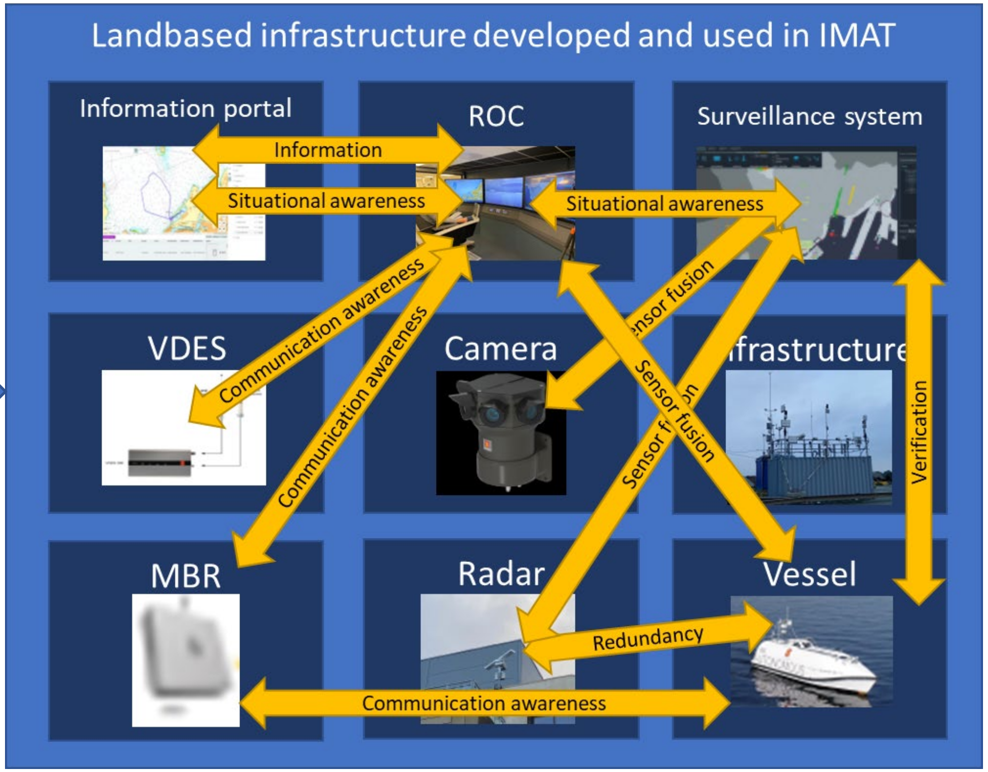
Demonstration

- **Scenario 0: Plan operasjon**
- Scenario 1: Normal operation
- **Scenario 2: Deviation planned route**
- Scenario 3: Loss of shore sensor
- **Scenario 4: Spoofing**
- Scenario 5: Loss of communication
- Scenario 6: Redundant ROC's
- **Scenario 7: Close quarter**
- Scenario 8: Approaching harbour

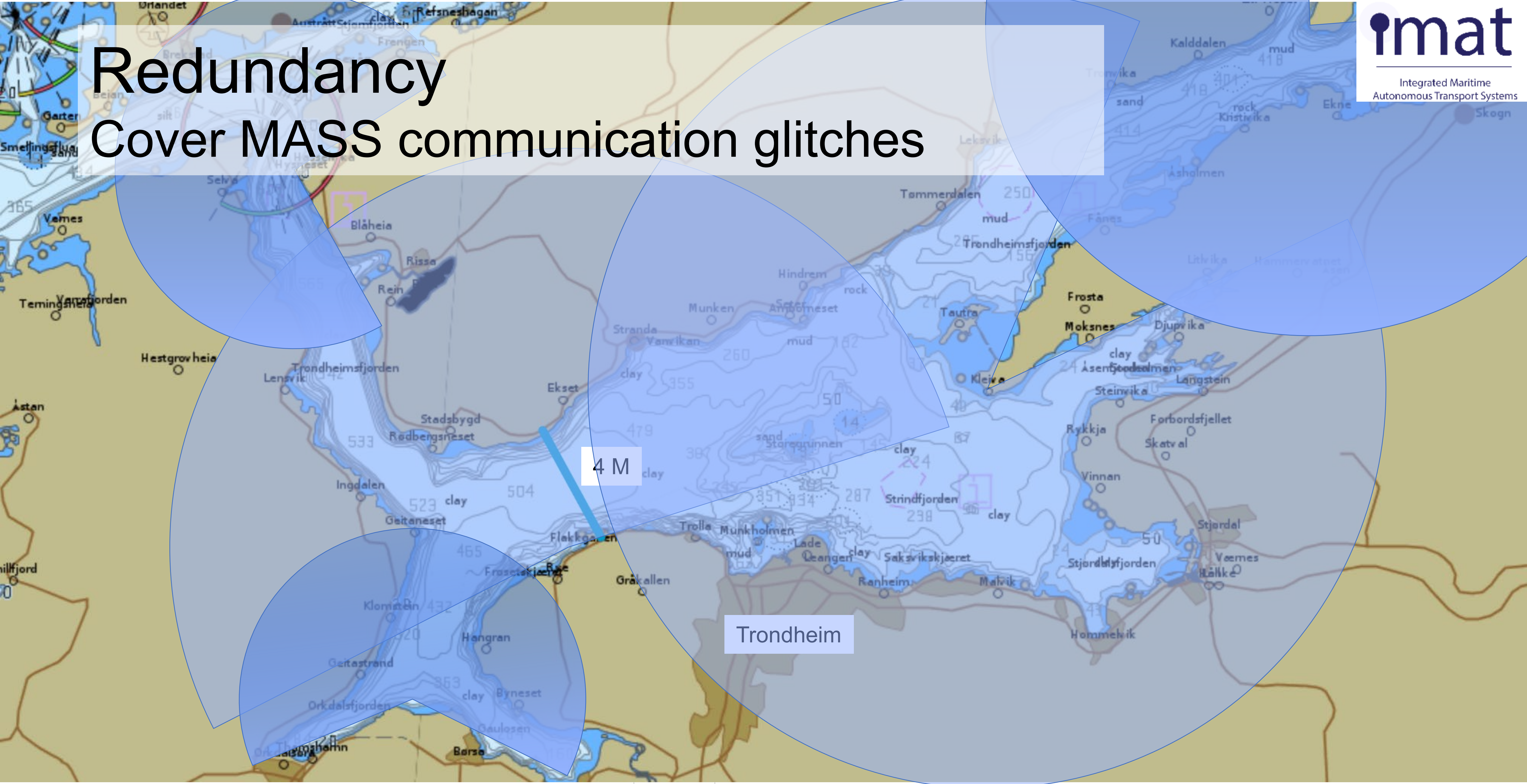
Some examples on IMAT possibilities …

Integrated Maritime
Autonomous Transport Systems





Redundancy
Cover MASS communication glitches



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Local information

Charging buoys, repair facilities, regattas, non-AIS craft tracking, …

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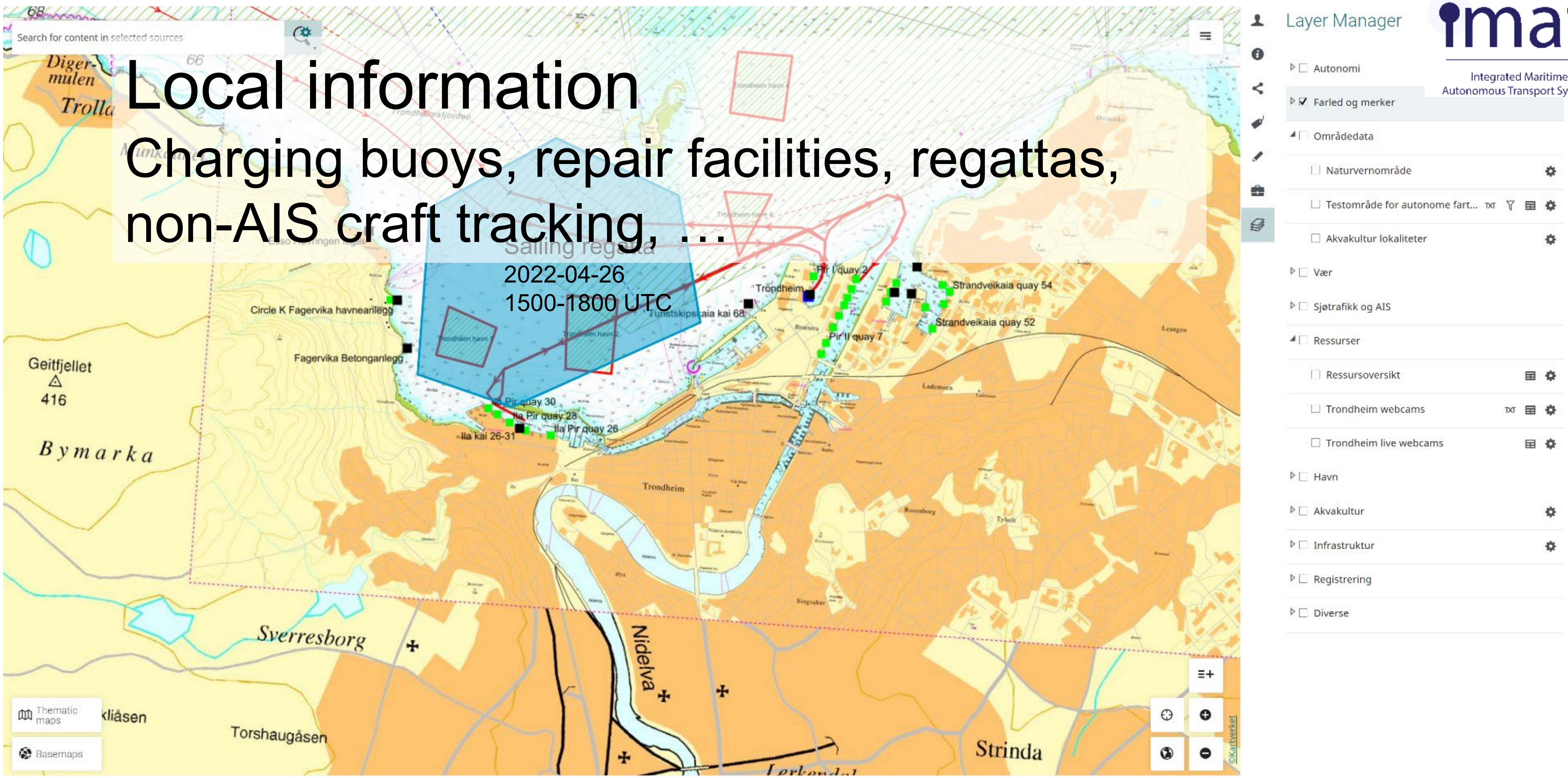
Local information

Charging buoys, repair facilities, regattas, non-AIS craft tracking, …



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Remote Operation Centre

Support and back-up, connectivity for AI digital twin

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Provocation:

LIC as a service – “A digital pilot”

A MASS Routing Service

e-Navigation

Route Exchange

"Intended and suggested routes"
RTZ route format (S-421)
"Moving Havens"

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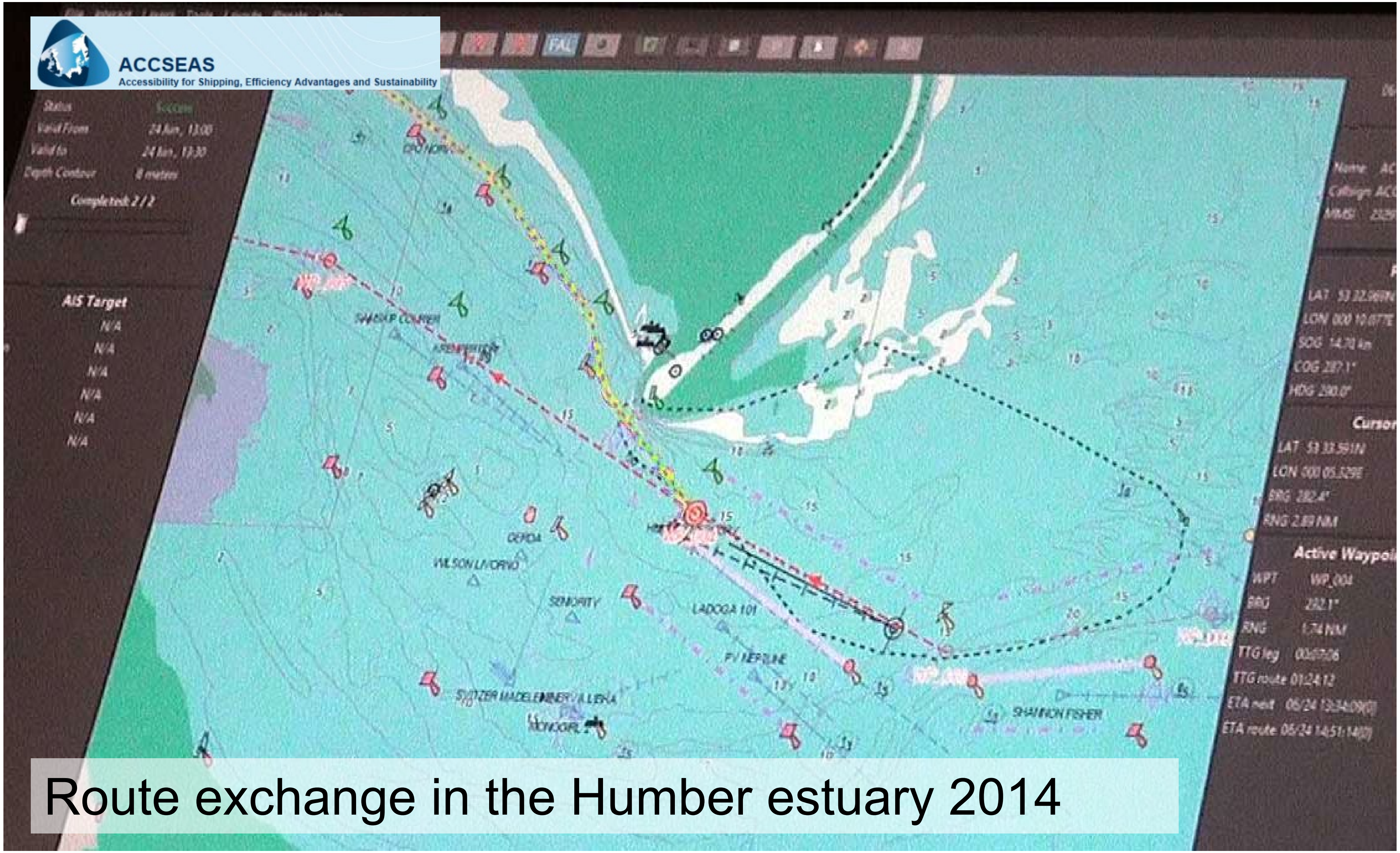

Route exchange in the Humber estuary 2014

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Ship destined for Trondheim from Rotterdam or Huston. Shore Control Centre in Huston or Manilla. Voyage planning to pilot station…

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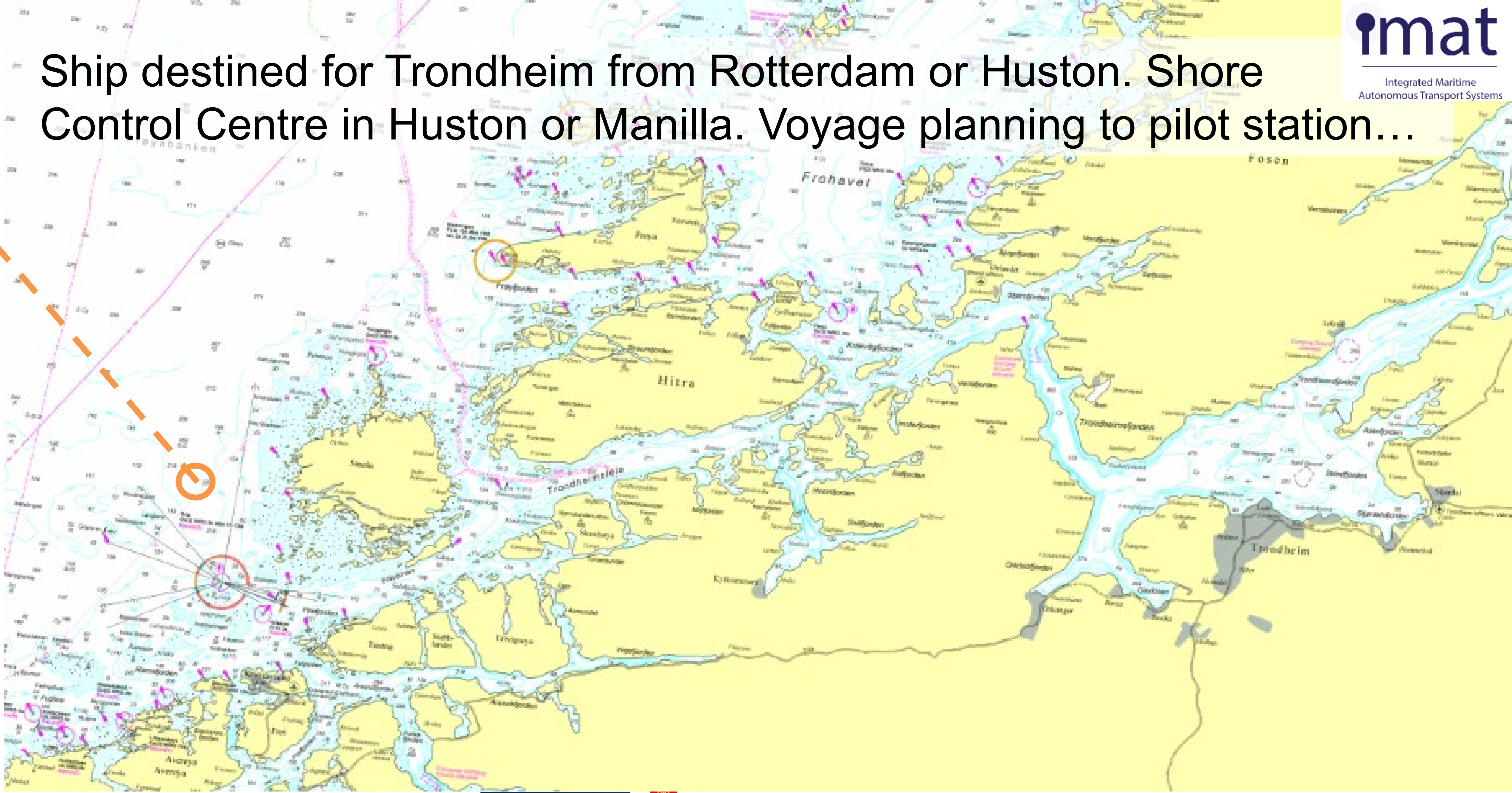

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routeinfo.no

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Info & Help Map & Search

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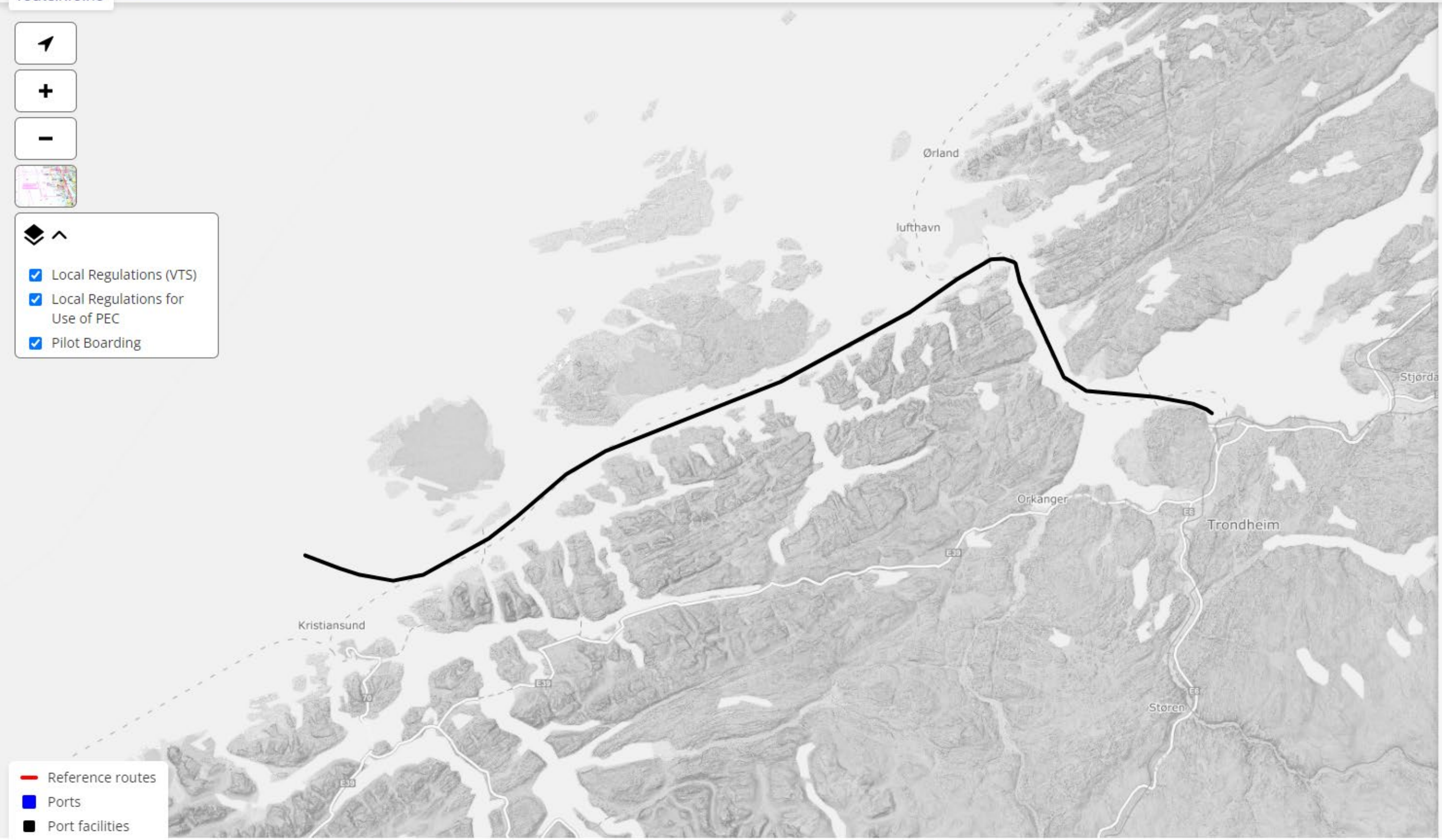

Local Regulations (VTS)
Local Regulations for Use of PEC
Pilot Boarding

Reference routes
Ports
Port facilities

Route: Trondheim_Gr

Routename: NCA_Trondheim_Grip_In_20211118.rtz

Download RTZ 1.0

Route Info

Sailing Distance: 88.8 nautical miles

Local Regulations for Use of PEC

150 meter LOA

Local Regulations (VTS)

None

VTS information

None

Connected locations

Ports incl. anchorage: Aure (Aure), Brekstad (Ørland), Hestvika (Hitra), Trondheim Anchoring (Trondheim), Lensvik (Orkland), Trondheim (Trondheim), Tjeldbergodden (Aure), Stavneset - Rissa (Indre Fosen), Ottersbogen (Ørland), Verrafjorden (Orkland), Vinjeora (Heim), Kvithylla (Indre Fosen), Selva (Orkland), Sandstad (Hitra), Storeflua (Hitra), Hemnskjela Anchorage (Heim), Garten (Ørland)

Port facilities: Hestvika Havneterminal (Hitra), Tjeldbergodden havneanlegg (Aure), Esso Høvringen lager (Trondheim), Circle K Fagervika havneanlegg (Trondheim), Ila kai 26-31 (Trondheim), Nyhavna Øst (Trondheim), Ladehammerkaia kai 57 (Trondheim), Pir 1 og Pir 2 (Trondheim), Transittkaia kai 41-43 (Trondheim), Turistskipskaia kai 68 (Trondheim), Hitra Kysthavn havneanlegg (Hitra), Vingvågen Havn (Hitra), Fagervika Betonganlegg (Trondheim)

Quays: Hestvika Havneterminal (Hitra), Esso Høvringen lager (Trondheim), Fagervika Terminal (Trondheim), Ila Pir quay 27 (Trondheim), Kullkranpiren quay 46 (Trondheim), Kullkranpiren quay 49 (Trondheim), Ladehammerkaia quay 55 (Trondheim), Ladehammerkaia quay 57 (Trondheim), Pir

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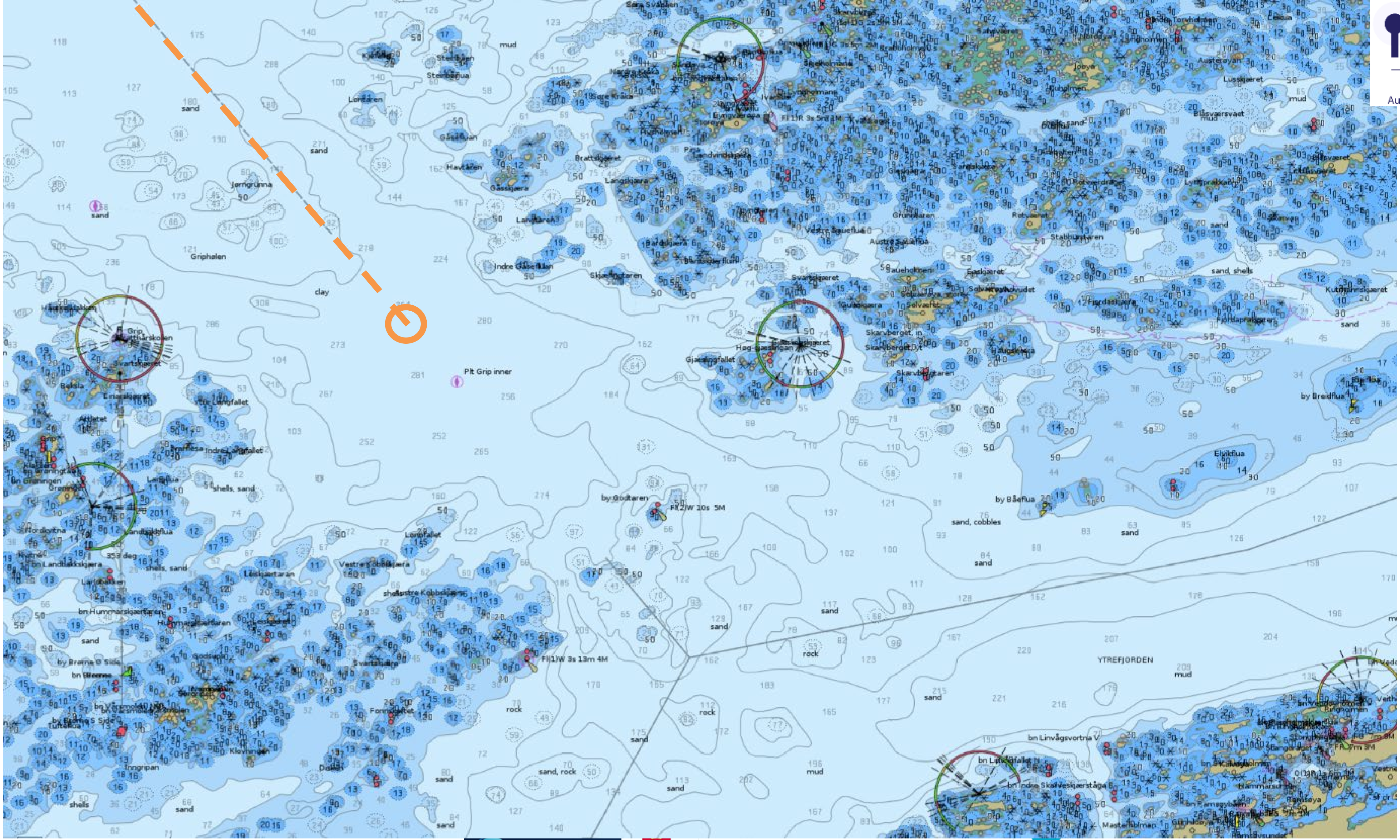

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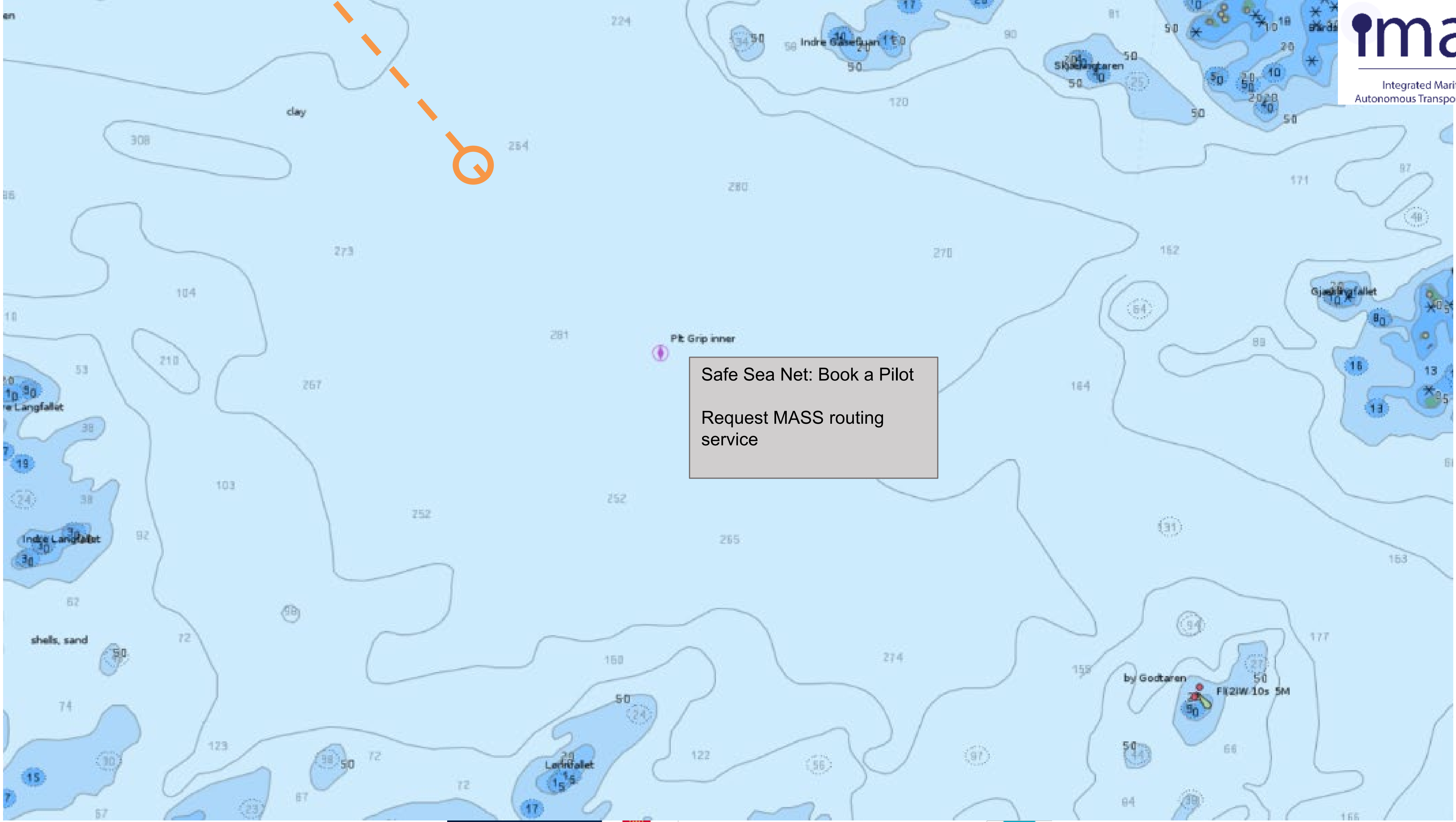

Safe Sea Net: Book a Pilot

Request MASS routing service

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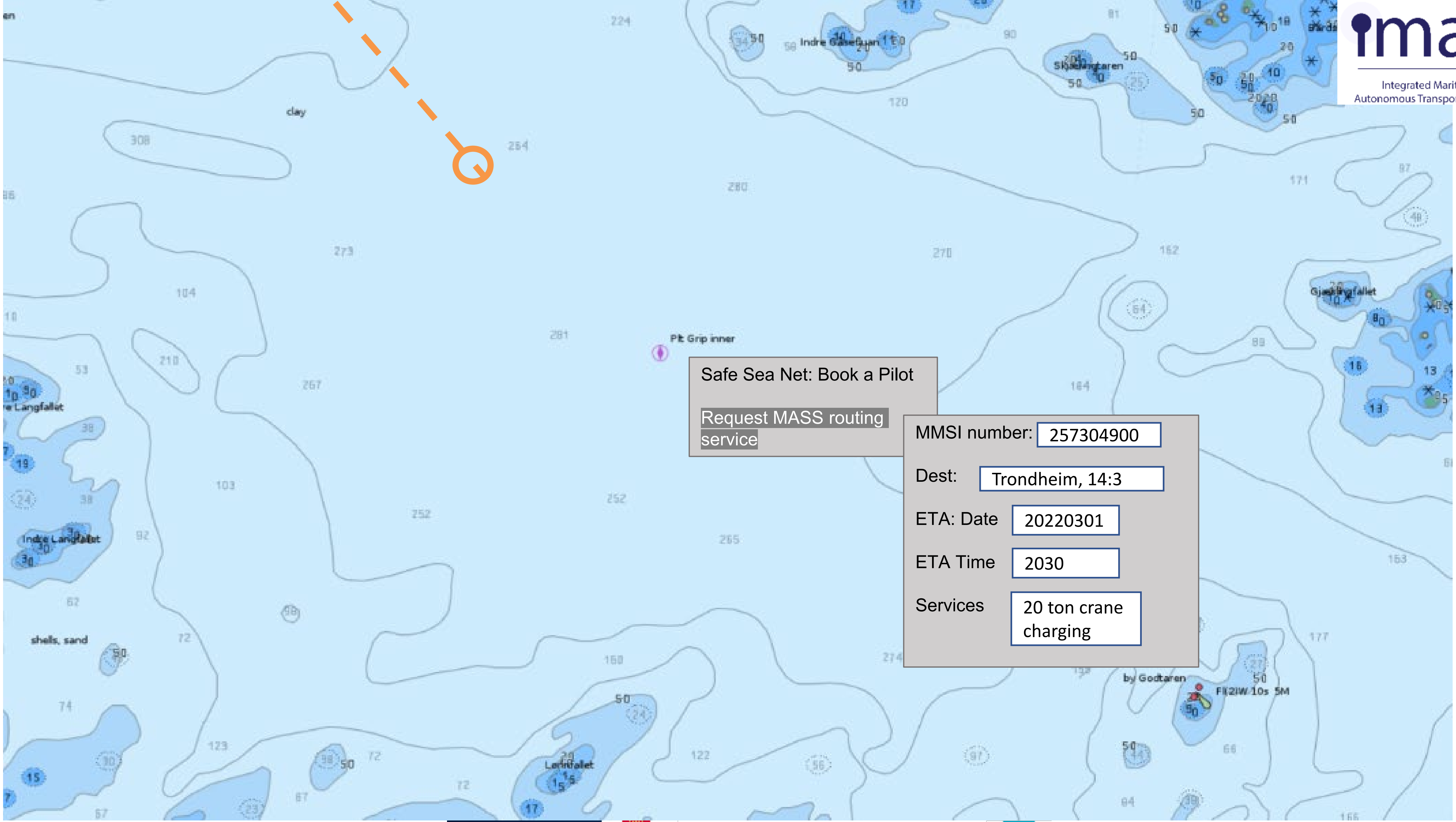

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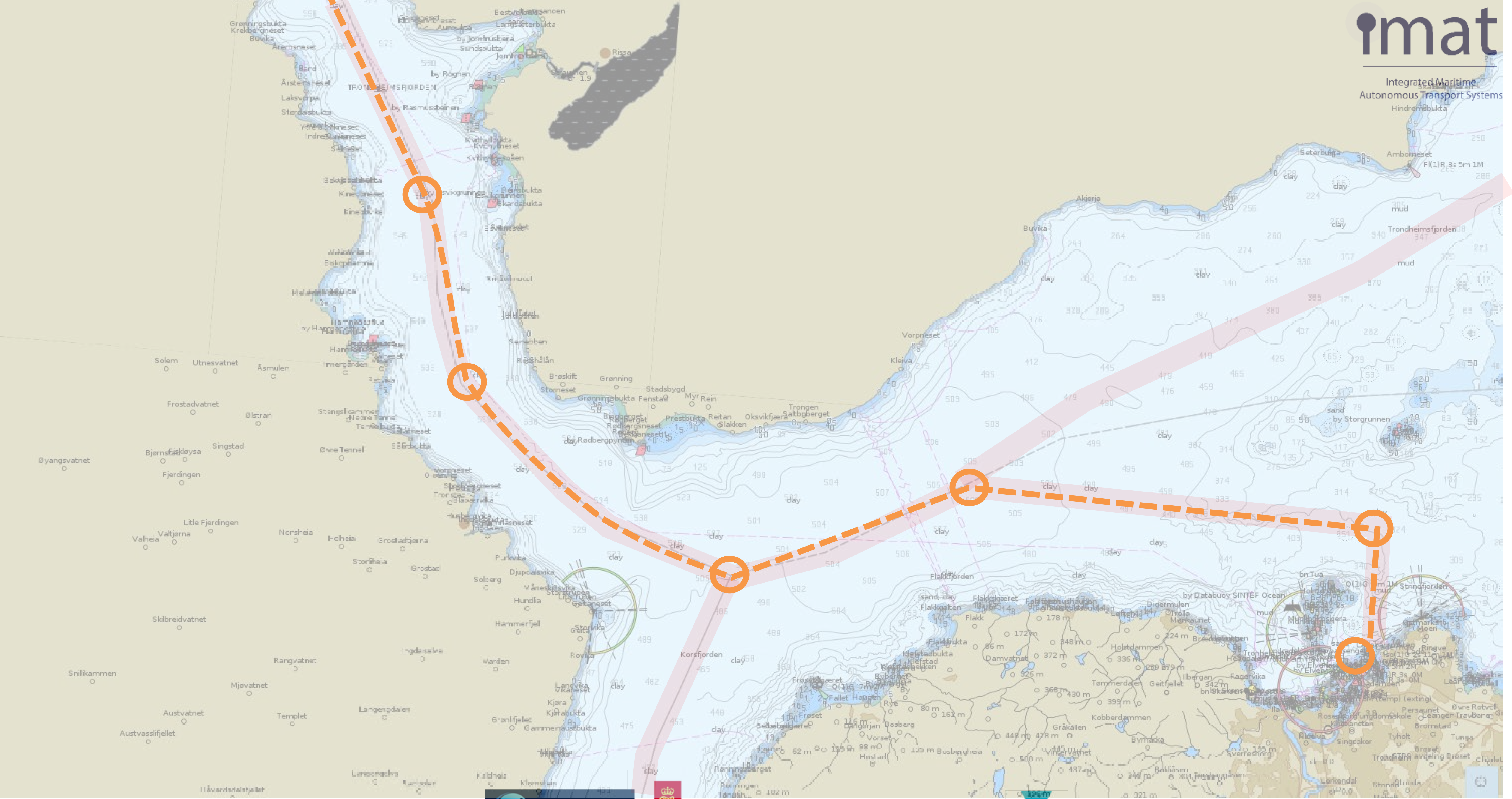

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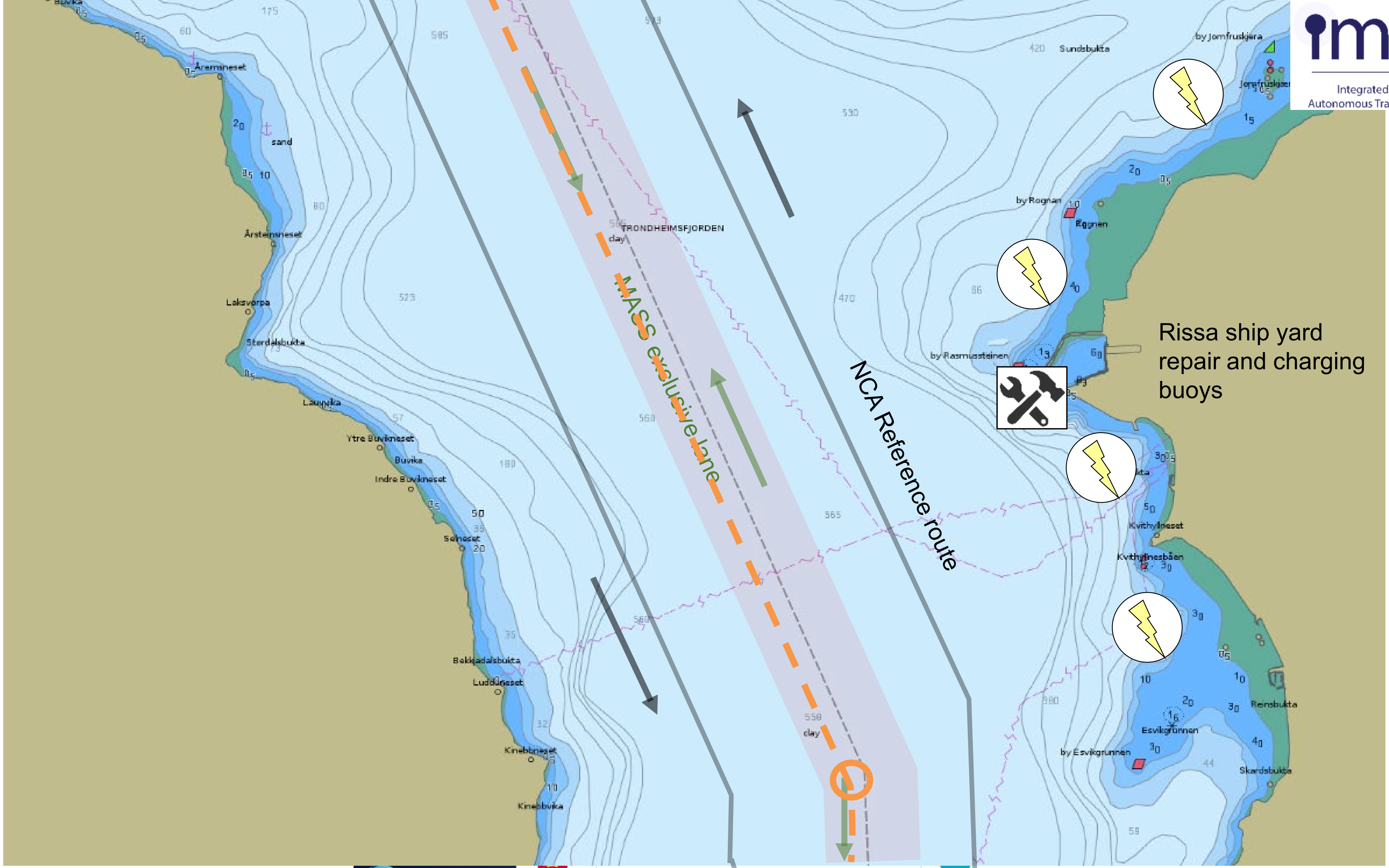

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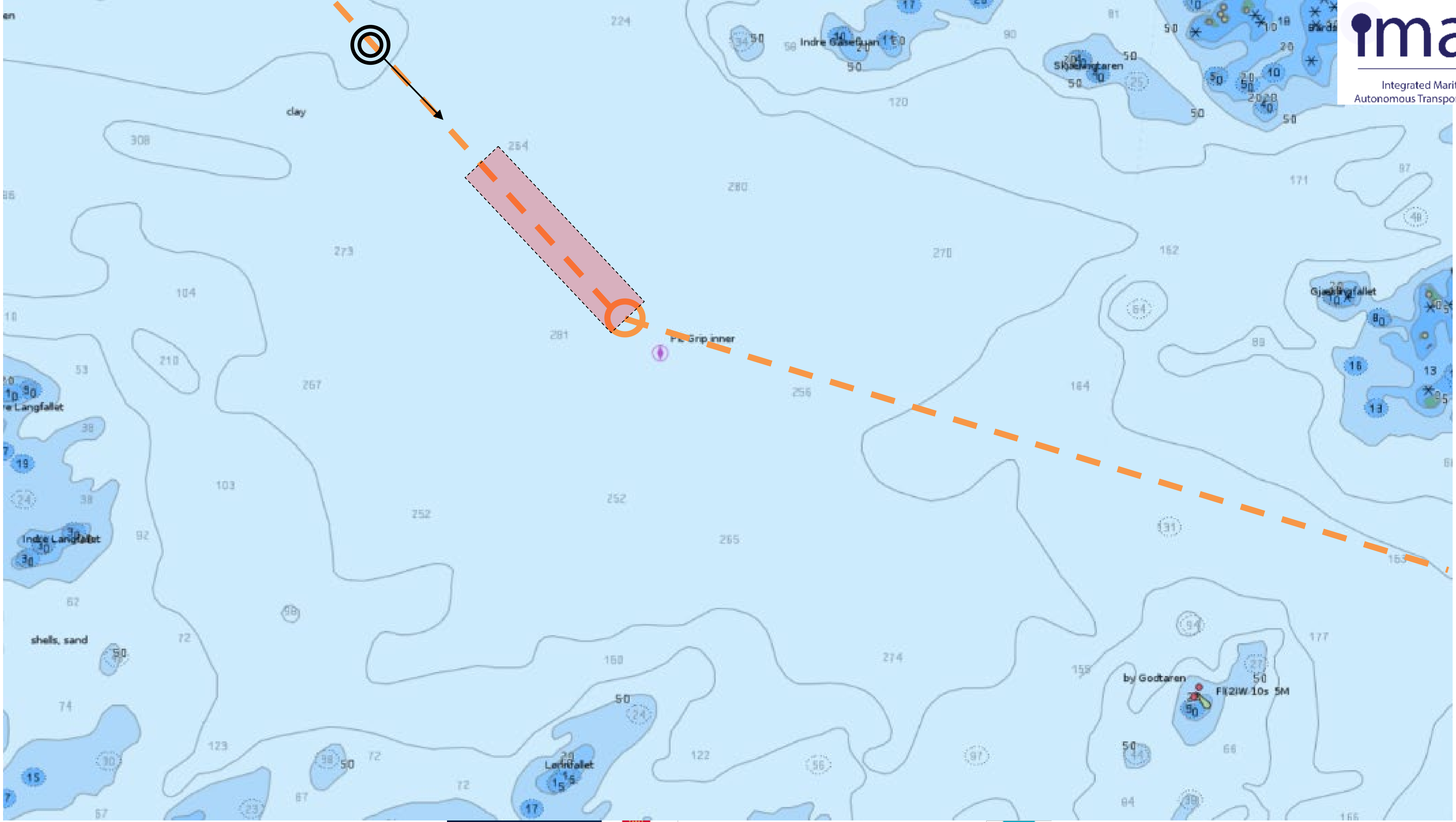
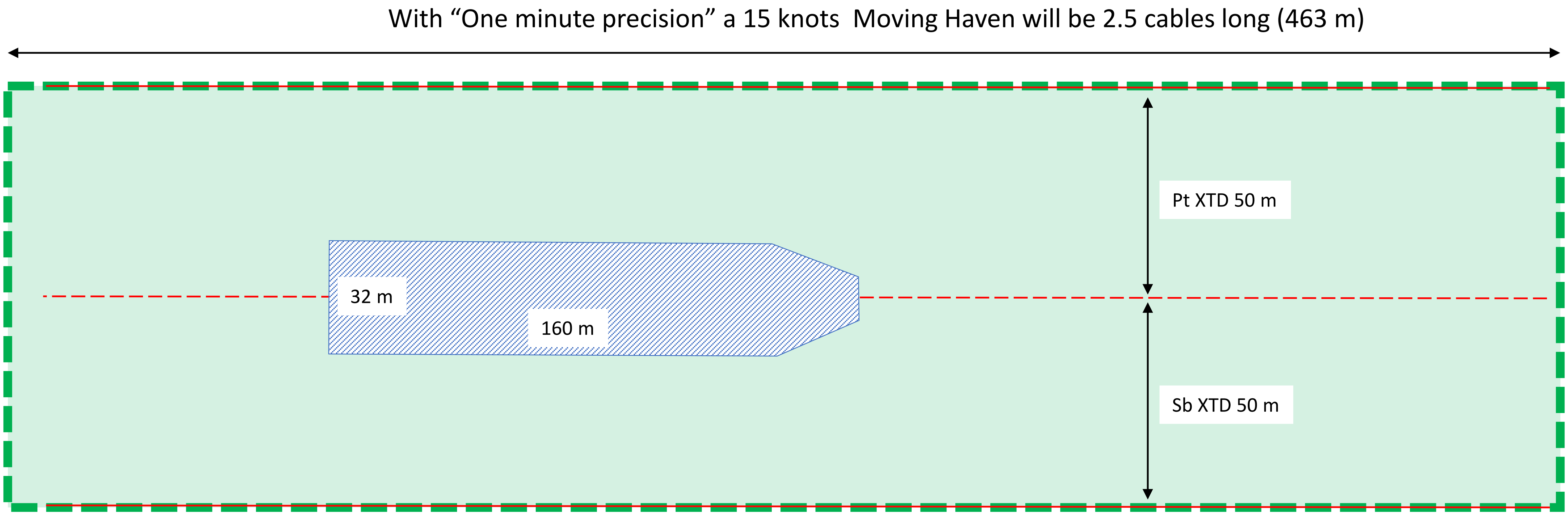

clay
shells, sand
Indre Langfallet
by Godtaren
Fl(2)W 10s 5M

Moving haven



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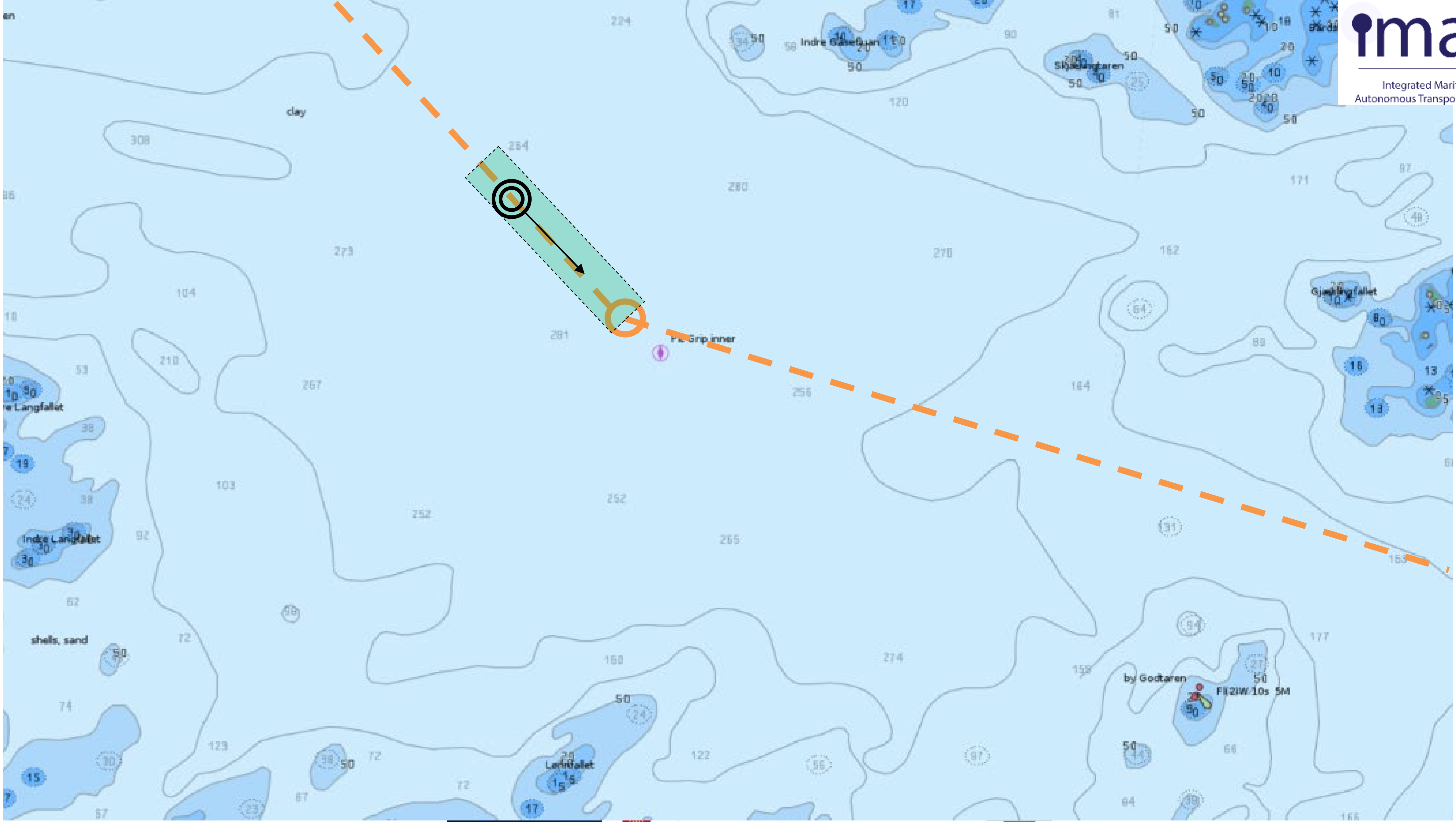

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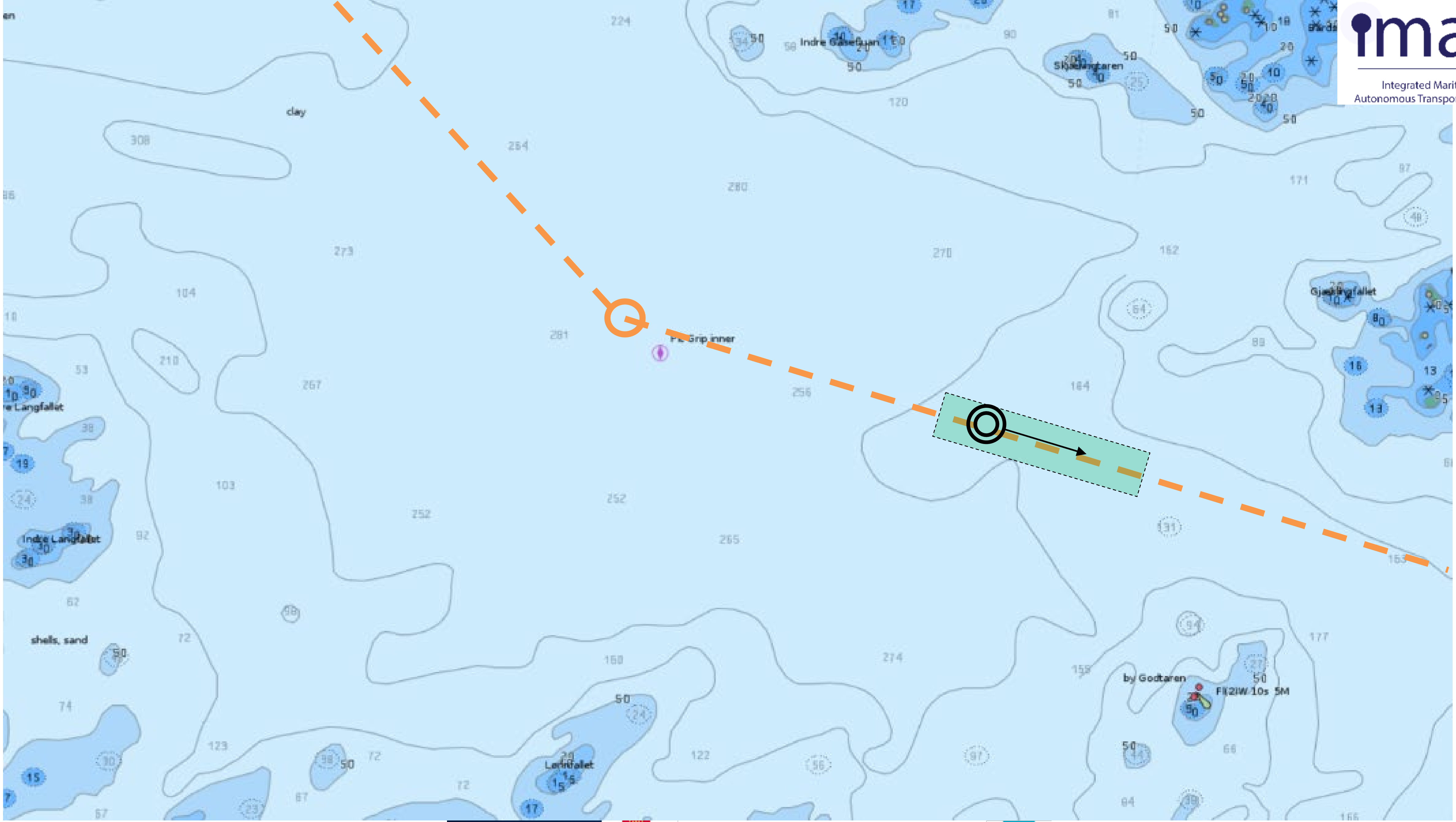

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Traffic separated fairway (time coordinated traffic - TOS)

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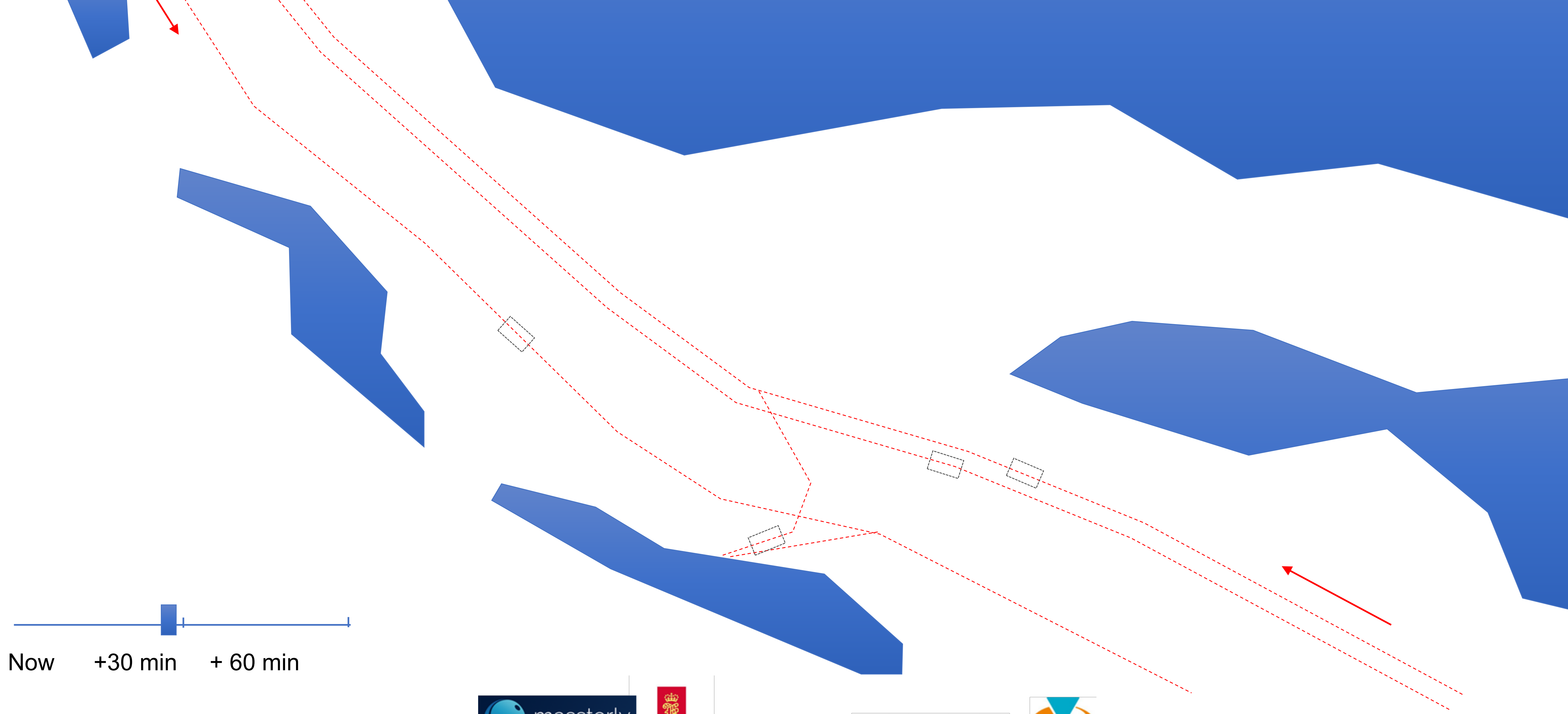

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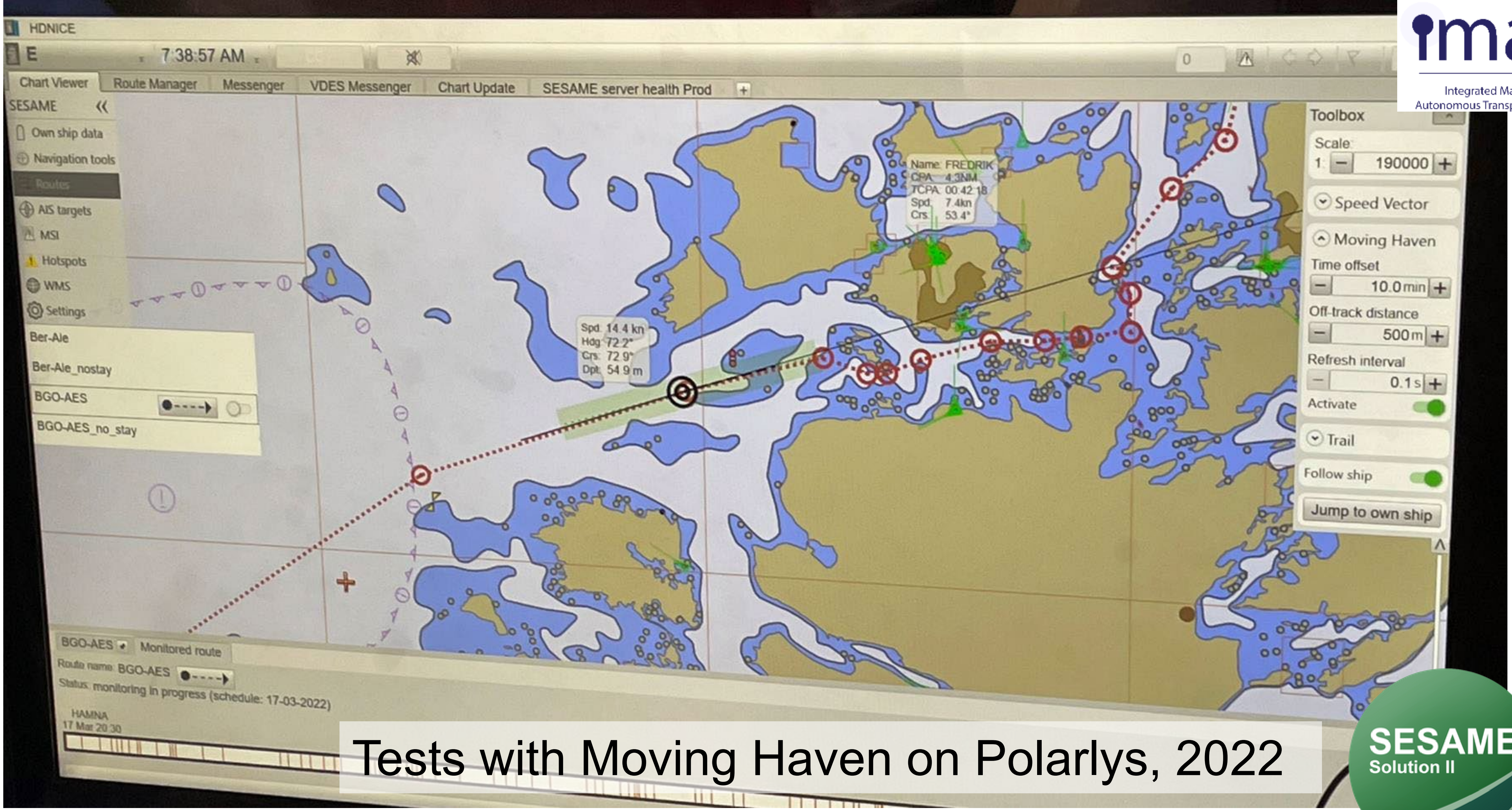

Tests with Moving Haven on Polarlys, 2022

A test version of the Moving Haven in a Kongsberg K-Master. 2022-03-18 onboard MV Polarlys, Norway.

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SESAME Solution II

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Possibilities – IMAT results

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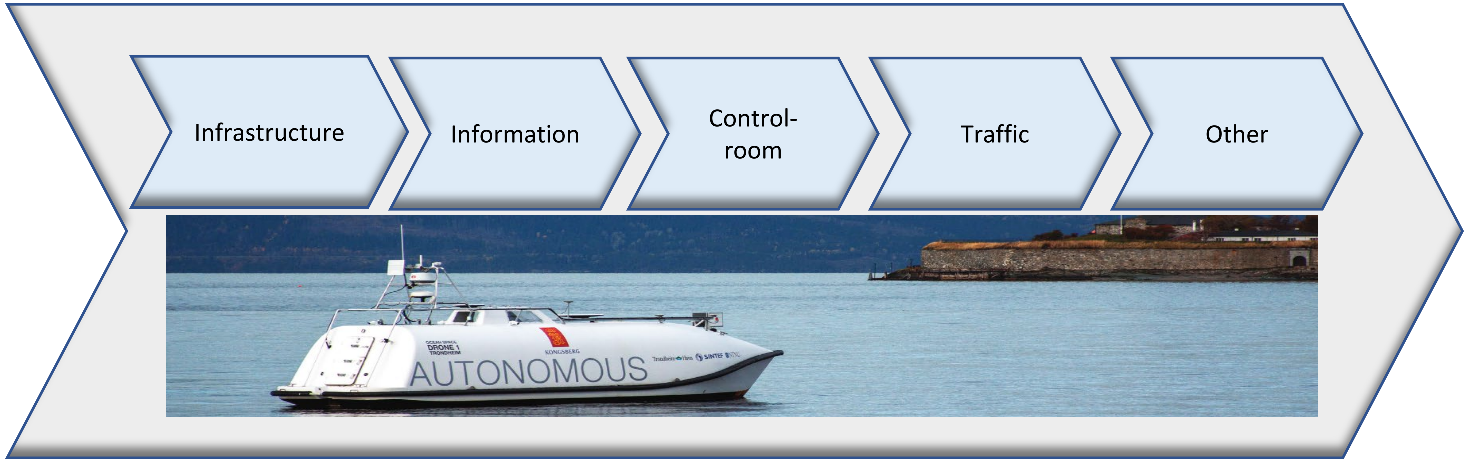
Service providers
- Using installed infrastructure in new project
- Further development of surveillance systems
- Information hub as a service
- Best practices
- New e-Nav services

Shipping companies, operators
- Use the infrastructure for verification of operation practices
- Control room functionalities
- Best practices
- New e-Nav services

Academia, research
- New knowledge
- Use the infrastructure in new projects
- LIC development
- New e-Nav services

Government, regulation, owners
- New standards and regulations?
- Test of equipment and infrastructure
- Validation of test results



Questions?

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Norwegian Maritime Authority
Trondheim Havn

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  https://www.sintef.no/projectweb/imat/